R. S. Jessup
9-11-53

NATIONAL BUREAU OF STANDARDS REPORT

2611

THERMODYNAMIC PROPERTIES OF MOLECULAR OXYGEN

Harold W. Woolley
Thermodynamics Section
Division of Heat and Power

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE

Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity. Resistance Measurements. Inductance and Capacitance. Electrical Instruments. Magnetic Measurements. Applied Electricity. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Gage.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Measurements. Infrared Spectroscopy. Nuclear Physics. Radioactivity. X-Rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. Atomic Energy Commission Instruments Branch.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Aerodynamics. Engineering Mechanics. Hydraulics. Mass. Capacity, Density, and Fluid Meters.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure. Chemistry of Mineral Products.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Machine Development.

Electronics. Engineering Electronics. Electron Tubes. Electronic Computers. Electronic Instrumentation.

Radio Propagation. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Frequency Utilization Research. Tropospheric Propagation Research. High Frequency Standards. Microwave Standards.

Ordnance Development.
Electromechanical Ordnance.
Ordnance Electronics.
These three divisions are engaged in a broad program of research and development in advanced ordnance. Activities include basic and applied research, engineering, pilot production, field testing, and evaluation of a wide variety of ordnance matériel. Special skills and facilities of other NBS divisions also contribute to this program. The activity is sponsored by the Department of Defense.

Missile Development. Missile research and development: engineering, dynamics, intelligence, instrumentation, evaluation. Combustion in jet engines. These activities are sponsored by the Department of Defense.

- Office of Basic Instrumentation
- Office of Weights and Measures.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
0302-50-2606	June 30, 1953	2611

THERMODYNAMIC PROPERTIES OF MOLECULAR OXYGEN

by

Harold W. Woolley
Thermodynamics Section
Division of Heat and Power

Sponsored in part by
National Advisory Committee for Aeronautics
Order No. W-5594

NBS

FOREWORD

This is one of a series of reports on the thermodynamic properties of gases compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It has been the purpose of the project on thermal properties of gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. The work was conducted under the supervision of Mr. Joseph Hilsenrath by members of the Thermodynamics Section, Division of Heat and Power.

Chas. W. Beckett
C. W. Beckett, Chief
Thermodynamics Section

R. E. Wilson
R. E. Wilson, Acting Chief
Division of Heat and Power

TABLE OF CONTENTS

Appendices

SUMMARY

The tables of thermal properties of molecular oxygen prepared for the NBS-NACA series are grouped together here for convenience in use. These tables include thermodynamic functions for the gas, both real and in the hypothetical ideal gas state, the transport properties of the gas, and the vapor pressure of the liquid. The ideal gas properties are given in tables 9.10 and 9.11. These include specific heat at constant pressure, enthalpy, entropy and the free energy function. For possible use with them, tables 10.10 and 10.11, giving the same properties for atomic oxygen, are also included. The real gas thermodynamic properties for molecular oxygen are given in tables 9.18 to 9.32 and include density, the compressibility factor or PV/RT, entropy, enthalpy, specific heat at constant pressure, the ratio of specific heats or C_p/C_v, and the velocity of sound at very low frequency. For tables 9.18 to 9.32, the tabular entries correspond to pressures of 0.01, .1, .4, .7, 1, 4, 7, 10, 40, 70 and 100 atmospheres. The temperature range covered is from 100°K or slightly higher, up to 3000°K. The method of correlation of the PVT data allows the calculation of approximate values for temperatures much higher than used in obtaining the experimental data. This is due to the determination of a reasonable representation of interaction energies between molecules, based on an over-all fitting of the available data.

The vapor pressure for liquid oxygen is given in table 9.50 with values at every 5 degrees from 55°K to 150°K for rapid use for these temperatures or when rough interpolated values are adequate. In a second part of the table, values of $\log_{10}P$ are tabulated more closely with uniformly spaced values of 1/T, permitting very accurate interpolation.

The viscosity, thermal conductivity and Prandtl number are given in tables 9.39, 9.42, and 9.44 respectively. The viscosity is tabulated for atmospheric pressure over the temperature range 100°K to 2000°K using the treatment of Hirschfelder, Bird and Spotz [17] for the Lennard-Jones 6-12 potential with the parameters ε/k = 100°K and b_o = 54.1 cm^3 $mole^{-1}$ chosen to fit the experimental data approximately over their entire range. The thermal conductivity was calculated from a purely empirical equation fitted to the experimental data, and the Prandtl number was computed in a straight-forward manner from these and the specific heat values.

I INTRODUCTION

This set of mutually consistent tables of thermodynamic properties of gaseous oxygen has been computed with the data of state represented by a pressure series whose temperature dependent coefficients and their derivatives were used to calculate the derived thermodynamic properties. As the experimental PVT data are more abundant than other relevant data, cover a wider range of temperature and pressure, and are usually dependable, the equation of state forms an appropriate starting point for the calculation of the entire field of thermodynamic properties.

In the representation of the PVT data for the NBS-NACA Tables, the objective was taken of covering adequately the limited range of pressure from zero to a maximum of 100 atmospheres and of temperature from a minimum of 100°K upward through the atmospheric and experimental range with a suitable extrapolation to high temperatures, but omitting the effect of dissociation. A discussion of the effects of dissociation is given in an earlier report [33]. As the tables were to be tabulated in terms of pressure for convenience of use, it seemed appropriate to make the correlation directly in terms of pressure. For most of the range of pressure and temperature desired, the simple equation

$$Z = PV/RT = 1 + B_1P + C_1P^2 + D_1P^3$$

appeared to be adequate. Here the coefficients B_1, C_1, and D_1, are functions of the temperature and are related to the virial coefficients in the analogous equation in powers of reciprocal

volume. As the equation was found not to fit as well as desired at the lowest temperatures for elevated pressures, the table entries have been limited to low pressures at low temperatures.

The pressure corrections to the various thermodynamic properties were determined theoretically from the correlation of the data of state. These were combined with values of properties for the ideal gas to obtain the complete real gas properties as given in tables 9.22 to 9.32. Many details concerning the actual computations will be found in later sections of this report and in the discussions of tables 9.20 to 9.32. Details concerning the calculation of the thermodynamic functions for the ideal gas will be found in the references given in tables 9.10 and 9.11.

The tables are given in dimensionless form and conversion factors to some frequently used units are given at the end of each table. The pressure intervals were chosen to facilitate Lagrangian interpolation of the tables. When linear interpolation in pressure is strictly valid, values for intermediate pressures have in some cases been omitted. Deviation plots have been included which indicate the agreement or discordance of the experimental data. The plots are also useful for showing the range and abundance or paucity of the experimental data for oxygen.

The tables were prepared in loose-leaf form to permit their prompt distribution to research workers. Close proximity between the tables and related conversion factors, text material and

deviation plots was sought. For convenience in preparation and use the existing loose leaf tables are brought together as the concluding portion of this report. The body of the report contains a general review of the experimental data and additional miscellaneous tables and charts pertaining to the correlation procedure and the final quality of the representation.

II SYMBOLS

Symbols	Definitions	Units and Dimensions
A	Abbreviation for Angstrom, unit of length	10^{-8}cm
a	Sound velocity at low frequency	m sec^{-1}, ft sec^{-1}
a_0	Sound velocity at standard conditions	314.82 m sec^{-1} 1032.9 ft sec^{-1}
B	Second virial coefficient in the 1/V series - a function of temperature	cm^3 mole^{-1}
$B^{(0)}(\tau)$	Second virial coefficient function $= B/b_o$	Dimensionless
B_1	Coefficient of P in the pressure series for PV/RT	atm^{-1}
B' and B''	TdB/dT and T^2d^2B/dT^2	cm^3 mole^{-1}
b_o	Characteristic parameter of the Lennard-Jones interaction potential	cm^3 mole^{-1}
b_2	b_o for pairs alone as distinct from pairs in larger clusters	54.7 cm^3 mole^{-1}
b_3	b_o for pairs within a cluster of three	48.18 cm^3 mole^{-1}
C	Third virial coefficient in the 1/V series, a function of temperature	(cm^3 mole^{-1})^2
$C^{(0)}(\tau)$	Third virial coefficient function $= C/b_o^2$ in simple theory	Dimensionless
C_1	Coefficient of P^2 in the pressure series for PV/RT	atm^{-2}
C_p	Heat capacity at constant pressure	various

Symbols	Definitions	Units and Dimensions
C_p^o	Heat capacity at constant pressure for the ideal gas	various
C_v	Heat capacity at constant volume	various
C_v^o	Heat capacity at constant volume for the ideal gas	various
D	Fourth virial coefficient in the 1/V series, a function of temperature	$(cm^3\ mole^{-1})^3$
D_1	Coefficient of P^3 in the pressure series for PV/RT	atm^{-3}
E	Internal energy for one mole of gas [E is also used for the fifth virial coefficient]	various
E_0^o	Internal energy for one mole of gas in standard ideal gas state at 0^oK. Same as H_0^o, the enthalpy for the same condition.	various
ΔE_0^o	The heat of formation for one mole of a substance in the standard state from its constituents in their standard states at 0°K. For atomic oxygen, equals half the dissociation energy for diatomic oxygen.	various
F	Free energy per mole	various
F^o	Free energy per mole in standard state [Ideal gas at one atmosphere for gaseous substances]	various
H	Enthalpy per mole	various
H^o	Enthalpy per mole in standard state [Ideal gas at one atmosphere for gaseous substances]	various

Symbols	Definitions	Units and Dimensions
H_0^o	Enthalpy per mole in standard ideal gas state. Same as E_0^o.	various
K	Equilibrium constant for a chemical reaction	$(atm)^n$
K	Symbol for degrees Kelvin	
k	Boltzmann constant for proportionality of energy to temperature	$.38048 \times 10^{-16}$ erg deg^{-1}
k	Thermal conductivity	cal cm^{-1} sec^{-1} $°C^{-1}$
k_0	Thermal conductivity at 273.16°K and one atmosphere pressure	5.867×10^{-5} cal cm^{-1} sec^{-1} $°C^{-1}$
M	Molecular weight	32 gm $mole^{-1}$
N	Avogadro's number	6.02283×10^{23} $mole^{-1}$
O	Symbol for (one atom of, or atomic) oxygen	
P	Pressure	atm, dyne cm^{-2}
P_0	Atmospheric pressure	1 atm; 1013250 dynes cm^{-2}
p	Subscript indicating constant pressure	
R	Gas constant per mole	82.0567 cm^3atm $°K^{-1}$$mole^{-1}$ 1.98718 cal $deg^{-1}$$mole^{-1}$ 8.31439 abs joule $deg^{-1}$$mole^{-1}$
r_0	Classical distance of closest intermolecular approach at zero energy according to Lennard-Jones potential	3.51 A from B 3.499 A from η
S	Entropy for one mole	various

Symbols	Definitions	Units and Dimensions
S^o	Entropy for one mole in standard state [Ideal gas at one atmosphere for gaseous substances]	various
T	Absolute temperature	degrees K degrees R
T_0	Temperature at standard conditions	273.16°K
V	Volume per mole	$cm^3\ mole^{-1}$
V	Function in theory of viscosity	Dimensionless
v	Subscript indicating constant volume	
W	Function in theory of viscosity	Dimensionless
x	Mole fraction	Dimensionless
Z	Compressibility factor	Dimensionless
Z_0	Compressibility factor at 273.16°K and one atmosphere	.99905
α	Isentropic expansion coefficient, $\frac{-V}{P}\left(\frac{dP}{dV}\right)_S = \frac{-V}{P}\left(\frac{dP}{dV}\right)_T \gamma$	Dimensionless
γ	Ratio of specific heats, C_p/C_v	Dimensionless
ε	Maximum energy of binding between molecules with a Lennard-Jones potential	ergs
ε/k	Characteristic parameter of the Lennard-Jones interaction potential	deg K
ε_2/k	ε/k for pairs alone	116°K
ε_3/k	ε/k for pairs within a cluster of three	124.7°K

Symbols	Definitions	Units and Dimensions
η	Viscosity	poises, gm sec^{-1} cm^{-1}
η_0	Viscosity at 273.16°K and one atmosphere	1919.2 X 10^{-7} poises
ν	Kinematic viscosity, η/ρ	cm^2 sec^{-1}
ν_0	Kinematic viscosity at 273.16°K and one atmosphere	.13430 cm^2 sec^{-1}
ρ	Density	mole cm^{-3}, gm cm^{-3} also Amagat units, etc.
ρ_0	Density at 273.16°K and one atmosphere	4.46564×10^{-5} mole cm^{-3} 1.42900×10^{-3} g cm^{-3}
τ	A reduced temperature, kT/ε	Dimensionless

III THE EXPERIMENTAL DATA OF STATE FOR OXYGEN

The experimental PVT data for oxygen extending to elevated pressure are indicated in Figure 1. The direct experimental values of Z are represented in the form of V(Z-1) plotted as a function of density, with temperatures in degrees Kelvin indicated adjacent to the plotted points. The deviations of the present correlation from the experimental points are evident by simple inspection of the graph.

The procedure used in the present correlation in representing the second and third virial coefficients, related to B_1 and C_1 in the pressure series, has been outlined in Ref. [32]. The method is so arranged as to permit use of such data as are available on the pressure dependence of internal energy, enthalpy, specific heat and sound velocity for the fitting of the second virial coefficient and has been arranged to permit fitting of Joule-Thomson data and PVT data for both second and third virial coefficients.

The data for oxygen at the ice point and room temperature seem quite dependable with measurements by Amagat [2], Holborn and Otto [18], Kuypers and Kamerlingh Onnes [22,25], and van Urk and Nijhoff [29]. The data of Amagat had their present usefulness mainly as an indication of the general trend toward higher pressure. The data of Holborn and Otto, as indicated by Cragoe [7], are subject to correction for the effect of stretching of the container at elevated pressure and for individual pressures and temperatures occurring in

their evaluation of the amount of substance present for individual measurements. The points as plotted in figure 1 are thus corrected and differ slightly from their reported numbers.

The adjustments made in selecting the Lennard-Jones parameters for pairs and clusters of three included some adjustment of the C_1 for failure to achieve the best possible low temperature fit of the B_1. The limitation to low pressure values at the low temperatures arises partly from this imperfection of representation. The primary objective in the present correlation was to represent the higher and intermediate temperature data for extrapolation to much higher temperatures. The present choice of parameters was a result of these requirements. A set of parameters more appropriate for the low temperature region by itself could similarly be arrived at.

In terms of the virial coefficients for 6-12 Lennard-Jones potentials as tabulated in the dimensionless form $B^{(0)}(\tau)$ and $C^{(0)}(\tau)$ by Bird, Spotz and Hirschfelder [4], the coefficients B_1 and C_1 were represented by

$$B_1 = b_2 \, B^{(0)}(\tau_2)/RT$$

and

$$C_1 = b_3^2 \, [C^{(0)}(\tau_3) - 4 \, (B^{(0)}(\tau_3))^2]/(RT)^2 + 3 \, B_1^2$$

where $\tau_2 = kT/\varepsilon_2$ and $\tau_3 = kT/\varepsilon_3$

with $\varepsilon_2/k = 116°K$, $b_2 = 54.7 \text{ cm}^3 \text{ mole}^{-1}$

and $\varepsilon_3/k = 124.7°K$, and $b_3 = 48.18 \text{ cm}^3 \text{ mole}^{-1}$.

D_1 was represented empirically as

$$D_1 = -483.037 \, T^{-4} + 251430 \, T^{-5} - 24.618 \times 10^6 \, T^{-6} - 38.426 \times 10^{-5} \, T^{-3} e^{1380/T}.$$

PVT data in the low temperature region have been represented with a density series using B and C only, by Claitor and Crawford [5] and by Hall and Ibele [15]. The density is intrinsically more suitable as a variable in this temperature region, as the pressure becomes particularly inappropriate near the critical point.

IV COMPARISON OF DERIVED QUANTITIES WITH THE EXPERIMENTAL DATA

Experimental data on heat capacity, entropy, enthalpy, sound velocity, etc., are too limited in extent to provide a tabulation of these properties directly. The tabulated values for these quantities are based on the correlation of the data of state and on the properties for the ideal gas. Thermodynamic properties thus calculated from good PVT data can be expected to agree well with good direct experimental data for the various quantities. This section presents a comparison of derived thermodynamic quantities with corresponding experimental data.

One single determination of the dependence of the internal energy of gaseous oxygen upon the pressure is given in the work of Rossini and Frandsen [26] for the pressure range zero to 40 atmospheres at 28°C. Their value was -6.51 joules atm^{-1} mole^{-1}. The corresponding theoretical value for the dependence at zero pressure according to the present correlation is -6.41_5 joule atm^{-1} mole^{-1}. The average value over the range zero to 40 atmospheres obtained by combining

values in Tables 9.10, 9.20 and 9.22 is approximately -6.55 joules atm^{-1} $mole^{-1}$. The average value as obtained by Meyers [23] based on his correlation of PVT data for oxygen is-6.47 joules atm^{-1} $mole^{-1}$.

The specific heat at constant pressure near atmospheric pressure was measured by Henry [16] using a flow method involving measurement of the lack of symmetry of temperature along a uniformly heated flow tube. He claimed an accuracy of no more than one percent except at 20°C where an accuracy of 1/2 percent was suggested. His results, given as specific heat at constant volume, have been read from his graph and are shown in Figure 1 of Table 9.24 as departures from the table values after reconversion to give the measured specific heat at constant pressure. His smoothed table of values has similarly been used to compute values for constant pressure which are shown in this graph by the dashed curve.

Values for the specific heat of gaseous oxygen were reported by Eucken and v. Lüde [10], obtained with the method of Lummer and Pringsheim based on the isentropic cooling during expansion. In this procedure, the formula

$$C_p = R\,[Z + T\,(\partial Z/\partial T)_p]\quad (d \ln P/d \ln T)_S$$

applies. Eucken and v. Lüde used PVT data of Holborn and Otto to evaluate the linear dependence on pressure of $Z + T\,(\partial Z/\partial T)_p$. Points indicating their reported values of C_p at one atmosphere and 302.6°K, 381.2°K and 478.9°K are shown in Figure 1 of Table 9.24.

Values for the specific heat of oxygen obtained by Wacker, Cheney and Scott [30] with a flow calorimeter at -30°C, 40.04°C and 90°C are also shown in this figure.

Values for the specific heat of oxygen computed from the sound velocities observed by Shilling and Partington [27] have also been included. These show large departures from theoretical values at elevated temperatures.

Measurements of the specific heat of gaseous oxygen at constant pressure were reported by Workman [34] for 26°C and 60°C for pressures from 10 kg/cm^2 to 130 kg/cm^2, or from 9.68 atm to 125.8 atm. In figure 2 of Table 9.24 his results are shown converted to the form of the ratio of specific heat observed to the specific heat of the ideal gas. The curves adjacent to the experimental points are the corresponding theoretical values based on the present correlation of the PVT data.

Measurements on the velocity of sound in gaseous oxygen in the temperature range 77°K to 90°K have been reported on by Keesom, van Itterbeek and van Lammeren [20] and by van Lammeren [28]. While the theoretical values agree fairly well with their results, the comparison is omitted from the present report on the basis that the PVT data on which the present tables are based are for higher temperatures.

Values for the velocity of sound in oxygen were obtained by Shilling and Partington [27] and by King and Partington [21] using a Kundt's tube. Their results are shown in Figure 1 of Table 9.32 as percent departures from the table, using sound velocity (a) directly

as measured and (b) relative to the velocity of sound in air, with the plotted points based on this observed ratio combined with the velocity in air at one atmosphere as given in Table 2.32 of the present series of NBS-NACA tables. It may be seen that the departures from the theoretical values are reduced somewhat by making the comparison on the basis of the ratio of the velocity of sound in oxygen to that in air.

The heat of vaporization of liquid oxygen is shown in figure 2, taken from the report by Furukawa and McCoskey [13] on air, oxygen, and nitrogen. Their new measurements as adjusted to the nearest tenth of degree in temperature, using the thermochemical calorie, give the values:

68.40°K	7418.2 abs j $mole^{-1}$	1773.0 cal $mole^{-1}$
76.00°K	7228.2 abs j $mole^{-1}$	1727.6 cal $mole^{-1}$
84.10°K	7004.9 abs j $mole^{-1}$	1674.2 cal $mole^{-1}$
91.30°K	6790.4 abs j $mole^{-1}$	1622.9 cal $mole^{-1}$

and at the boiling point of 90.19°K, 6824.8 abs j $mole^{-1}$, or 1631.2 cal $mole^{-1}$ by interpolation.

A comparison of the calorimetrically determined entropy for gaseous oxygen at the boiling point with the entropy as calculated statistically from spectroscopic data is shown in table 9.01. The calorimetric data are from Giauque and Johnston [14], with the adjustment to the newer values of boiling point and latent heat shown for the calorimetric value and with the entropy based on the values of table 9.10. The estimated correction for non-ideality

at the boiling point on the basis of the extrapolation of the present P and P^2 coefficients is also given. Although the previous comparison of calorimetric and spectroscopic entropy was fairly satisfactory, in that the discrepancy was only .06 entropy units with an uncertainty given as 0.1 entropy units, the new comparison gives an even closer agreement, to about .02 entropy units.

V CALCULATION OF THE TABLES

The thermodynamic quantities tabulated in this report were computed numerically from the coefficients of the equation of state. The following formulas were used:

$$Z = PV/RT = 1 + B_1P + C_1P^2 + D_1P^3$$

$$S/R = S^o/R - k \ln P - (B_1 + TdB_1/dT)P - 1/2\,(C_1 + TdC_1/dT)P^2$$
$$- 1/3(D_1 + TdD_1/dT)P^3$$

$$H/RT = H^o/RT - T\ (dB_1/dT)P - 1/2\ T\ (dC_1/dT)P^2$$
$$- 1/3\ T\ (dD_1/dT)P^3$$

$$C_p/R = C_p^o/R - [2TdB_1/dT + T^2d^2B_1/dT^2]P$$
$$- 1/2\ [2TdC_1/dT + T^2d^2C_1/dT^2]P^2$$
$$- 1/3\ [2TdD_1/dT + T^2d^2D_1/dT^2]P^3$$

$$\frac{C_p - C_v}{R} = \frac{[Z + T\ (\partial Z/\partial T)_P]^2}{[Z - P\ (\partial Z/\partial P)_T]}$$
$$= \frac{[1 + (B_1 + TdB_1/dT)\ P + (C_1 + TdC_1/dT)P^2 + (D_1 + TdD_1/dt)P^3]^2}{[\ 1 - C_1P^2 - 2\ D_1P^3]}$$

$$a = \sqrt{RT\alpha Z/M} = Z\sqrt{\frac{RT\gamma}{M[Z - P(\partial Z/\partial P)_T]}}$$

VI CONCLUSION

The uncertainty of the tabulated density and compressibility and of the various derived properties for oxygen is discussed in the text adjacent to each table. The region in which the data are most dependable is probably near room temperature. The extensive data below room temperature are thought to be nearly as dependable. For the higher temperatures there is some lack of agreement between the results of Holborn and Otto and of Amagat for oxygen, so that this region may be regarded as particularly less certain. In the region immediately above and below the ice point the correlation is fitted fairly closely to the data, with an uncertainty probably not exceeding 0.1 percent in PV/RT or about 10 percent of the difference between real and ideal values. The uncertainty is larger at both higher and lower temperatures due to imperfections of theory and data. The derived pressure corrections to thermodynamic properties are in general less accurate, because in the differentiation process errors are propagated with a large increase. The corresponding experimental determinations are frequently inaccurate. The knowledge of the properties of oxygen can be improved by better experimental measurements, increase of the experimental range, and by improvement of applicable theory.

VII REFERENCES

[1] H. Alt, Über die Verdampfungswärme des flüssigen Sauerstoffs und flüssigen Stickstoffs und deren Änderung mit der Temperatur, Ann. Physik 19, 739(1906).

[2] E. H. Amagat, Memoires sur l'élasticité et la dilatabilité des fluides jusqu'aux très hautes pressions, Ann. chim. phys. 29, 68(1893).

[3] H. Barschall, Über die Verdampfungswärme des Sauerstoffes, Z. Elektrochem. 17, 345(1911).

[4] R. B. Bird, E. L. Spotz and J. O. Hirschfelder, The Third Virial Coefficient for Non-Polar Gases, J. Chem. Phys. 18, 1395(1950).

[5] L. C. Claitor and D. B. Crawford, Thermodynamic Properties of Oxygen, Nitrogen and Air, Preprint American Society of Mechanical Engineers, Towne Scientific School, University of Pennsylvania, p. 3, Nov. 19 (1948).

[6] K. Clusius and F. Konnertz, Ergebnisse der Tieftemperaturforschung - VI. Kalorimetrische Messungen der Verdampfungswärme des Sauerstoffs bei normalem Druck sowie des Aethylens und Propylens unterhalb und oberhalb vom Atmosphärendruck, Z. Naturforsch, 4A, 117(1949).

[7] C. S. Cragoe, Slopes of pv Isotherms of He, Ne, A, H_2, N_2 and O_2 at 0°C, J. Research Nat. Bur. Standards 26, 495(1941) RP-1393.

[8] L. I. Dana, The Latent Heat of Vaporization of Liquid Oxygen-Nitrogen Mixtures, Proc. Am. Acad. Arts Sci. 60, 241(1925).

[9] J. Dewar, Studies with the Liquid Hydrogen and Air Calorimeters, Proc. Roy. Soc. (London), 76A, 325(1905).

[10] A. Eucken and K. v. Lüde, Die spezifische Wärme der Gase bei mittleren und hohen Temperaturen. I. Die spezifische Wärme der Gase: Luft, Stickstoff, Sauerstoff, Kohlenoxyd, Kohlensäure, Stickoxydul und Methan zwischen 0° und 220°C. Z. physik. Chem. B5, 413(1929).

[11] A. Eucken, Über das thermische Verhalten einiger Komprimierter und Kondensierter Gase bei tiefen Temperaturen, Verhandl. deut. physik. Ges. 18, 4(1916).

[12] A. Frank and K. Clusius, Präzisionsmessungen der Verdampfungswärme der Gase O_2, H_2S, PH_3, A, COS, CH_4 und CH_3D, Z. physik. Chem. B42, 395(1939).

[13] G. T. Furukawa and R. E. McCoskey, The Condensation Line of Air and the Heats of Vaporization of Oxygen and Nitrogen, Technical Report to National Advisory Committee For Aeronautics, Report 1775, National Bureau of Standards (1952).

[14] W. F. Giauque and H. L. Johnston, The Heat Capacity of Oxygen from 12°K to its Boiling Point and its Heat of Vaporization. The Entropy from Spectroscopic Data. J. Am. Chem. Soc. 51, 2300(1929).

[15] N. A. Hall and W. E. Ibele, Thermodynamic Properties of Air, Nitrogen and Oxygen as Imperfect Gases, Technical Paper of the University of Minnesota Institute of Technology, Engineering Experiment Station, Technical Paper No. 85, December (1951).

[16] P. S. H. Henry, The Specific Heats of Air, Oxygen, Nitrogen from 20°C to 370°C, Proc. Roy. Soc. (London) A133, 492(1931).

[17] J. O. Hirschfelder, R. B. Bird, and E. L. Spotz, Viscosity and other physical properties of gases and gas mixtures. Trans. ASME 48, 921(1949).

[18] L. Holborn and J. Otto, Über die Isothermen einiger Gase zwischen 400° und -183°, Z. Physik 33, 1(1925).

[19] W. H. Keesom, The Heat of Vaporization of Hydrogen, Commun. Phys. Lab. Univ. Leiden, No. 137e (1914).

[20] W. H. Keesom, A. van Itterbeek, and J. A. van Lammeren, Measurements about the velocity of sound in oxygen gas, Proc. Acad. Sci. Amsterdam 34, 996(1931); Leiden Comm. 216 d.

[21] F. E. King and J. R. Partington, Measurements of Sound Velocities in Air, Oxygen, and Carbon Dioxide at Temperatures from 900°C to 1200°C with Special Reference to the Temperature Coefficients of Molecular Heats, Phil. Mag. 9, 1020(1930).

[22] H. A. Kuypers and H. Kamerlingh Onnes, Isothermes de substances diatomiques et de leurs melanges binaires XXII. Isothermes de l'oxygène à 0° et 20°C. Leiden Comm. No. 165a (1923). Also see ref. [25].

[23] C. H. Meyers, Pressure-Volume-Temperature Data for Oxygen, J. Research Nat. Bur. Standards 40, 457(1948) RP-1891.

[24] G. P. Nijhoff and W. H. Keesom, Isotherms of di-atomic substances and their binary mixtures XXXIII. Isotherms of oxygen between -40°C and -152.5°C and pressures from 3 to 9 atmospheres. Leiden Comm. No. 179b (1925).

[25] H. K. Onnes and H. A. Kuypers, Isotherms of diatomic substances and their binary mixtures. XXV. On the isotherms of oxygen at low temperatures. Leiden Comm. No. 169a (1924).

[26] F. D. Rossini and M. Frandsen, The Calorimetric Determination of the Intrinsic Energy of Gases as a Function of the Pressure. Data on Oxygen and its Mixtures with Carbon Dioxide to 40 Atmospheres at 28°C , J. Research Nat. Bur. Standards 9, 733(1932) RP-503.

[27] W. G. Shilling and J. R. Partington, Measurements of the Velocity of Sound in Air, Nitrogen and Oxygen, with Special Reference to the Temperature Coefficients of the Molecular Heats, Phil. Mag. 6, 920(1928).

[28] J. A. van Lammeren, Second virial coefficient and specific heats of oxygen, Leiden Comm. Supplement No. 77b, also Physica 2, 833(1935).

[29] A. Th. van Urk and G. P. Nijhoff, Isotherms of diatomic substances and their binary mixtures. XXVII. On the isotherms of oxygen at 20°, 15.6° and 0°C. Leiden Comm. 169c (1925).

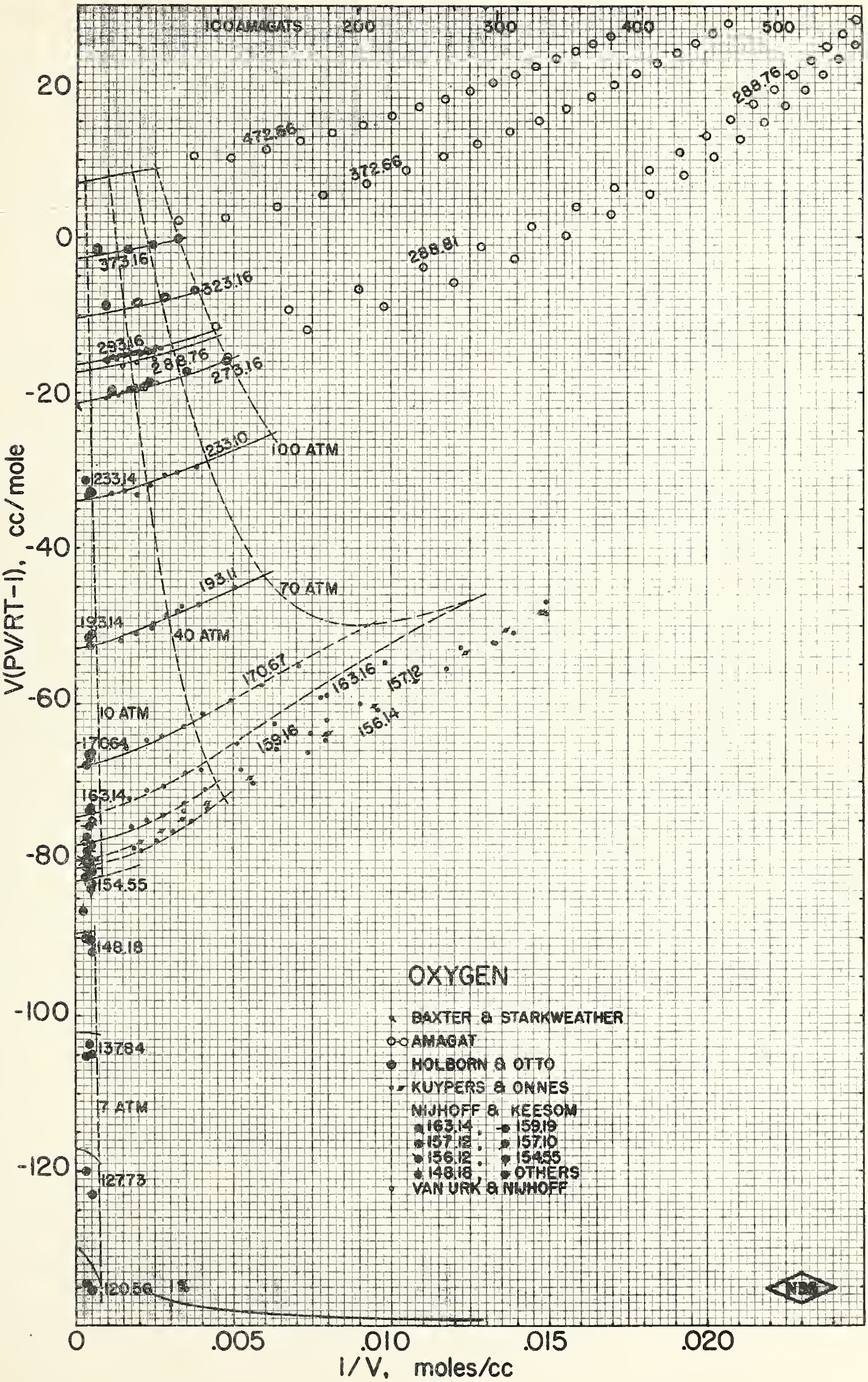
[30] P. F. Wacker, R. K. Cheney and R. B. Scott, Heat Capacities of Gaseous Oxygen, Isobutane, and 1-butene from -30° to 90°. J. Research Natl. Bur. Standards 38, 651-9(1947) RP-1804.

[31] G. Witt, Über die Verdampfungswärme flüssiger Luft, Arkiv Mat. Astron. Fysik 7, No. 32(1912).

[32] H. W. Woolley, The Representation of Gas Properties in Terms of Molecular Clusters, J. Chem. Phys. 21, 236(1953).

[33] H. W. Woolley, The Effect of Dissociation on the Thermodynamic properties of Pure Diatomic Gases, Report 1884, National Bureau of Standards, (1952).

[34] E. J. Workman, The Variation of the Specific Heats (C_p) of Oxygen, Nitrogen and Hydrogen with Pressure, Phys. Rev. 37, 1345(1931).



100 AMAGATS
200
300
400
500
20
0
-20
-40
-60
-80
-100
-120
V(PV/RT-1), cc/mole
0
.005
.010
.015
.020
1/V, moles/cc
472.66
372.66
288.81
288.76
373.16
323.16
293.16
288.76
273.16
233.10
233.14
100 ATM
193.11
70 ATM
193.14
40 ATM
170.67
163.16
157.12
156.14
159.16
10 ATM
170.64
163.14
154.55
148.18
137.84
7 ATM
127.73
120.56
1%
OXYGEN
BAXTER & STARKWEATHER
AMAGAT
HOLBORN & OTTO
KUYPERS & ONNES
NIJHOFF & KEESOM
163.14 , 159.19
157.12 , 157.10
156.12 , 154.55
148.18 , OTHERS
VAN URK & NIJHOFF
NBS

Fig. 1

HEAT OF VAPORIZATION OF OXYGEN

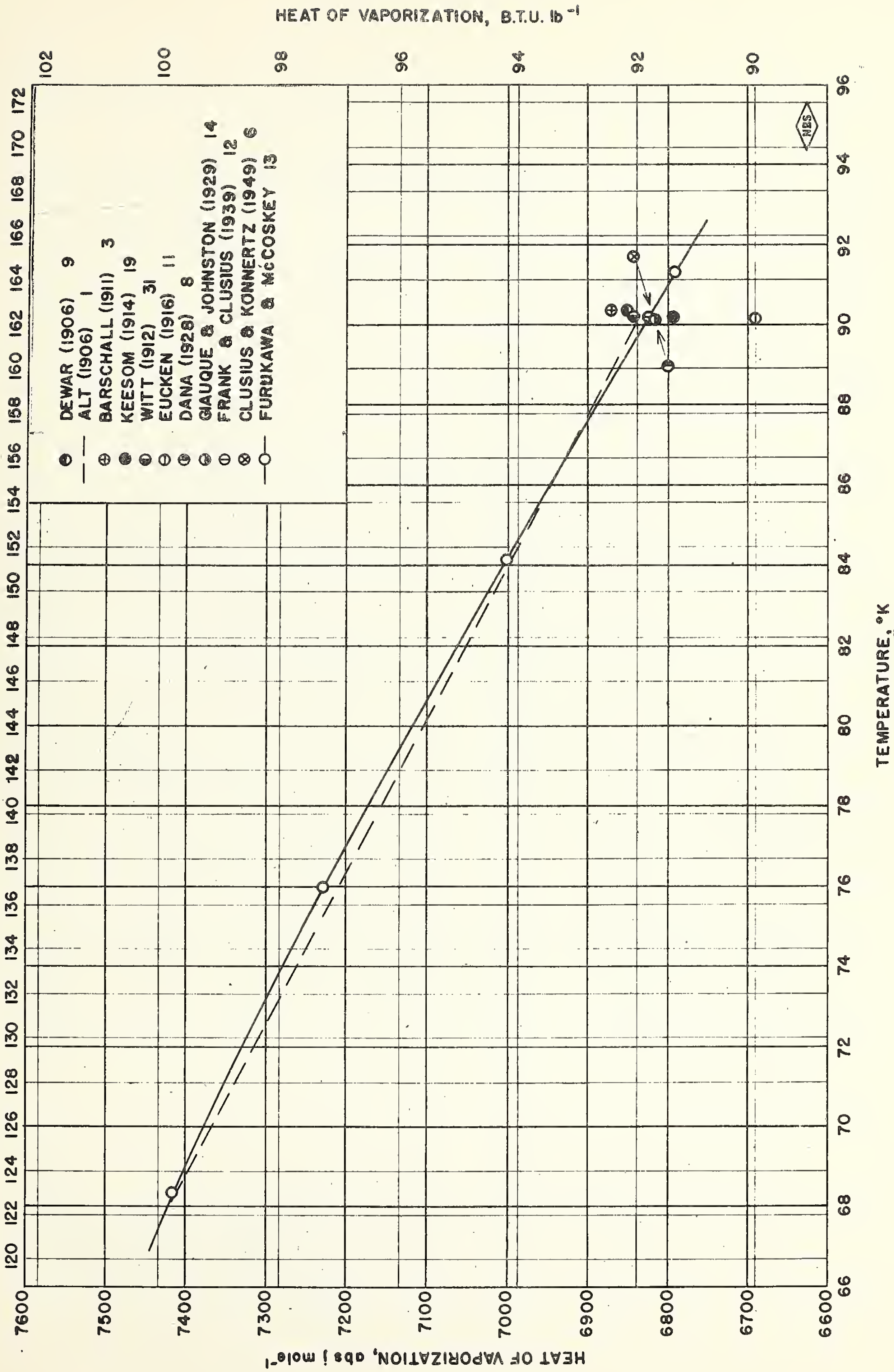


FIG.2.

TABLE 9.01 Entropy of Oxygen Vapor at Boiling Point

<u>Calculation Using 90.13°K as Boiling Point</u>			(1)
S for liquid at 90.13°K	22.498 E. U.		(1)
ΔS_{vap} at 90.13°K = 1628.8/90.13	18.07		(1)
S for vap.	40.57		(1)
S° spect. for gas	40.679		
		S°−S = .11 E. U.	
<u>Calculation Using 90.19°K as Boiling Point</u>			(2)
S for liquid at 90.13°K	22.498 E. U.		(1)
$(S_{90.19°K} - S_{90.13})$ for liquid	.009	from $\frac{12.96 \times .06}{90.15}$	(1)
S for liquid at 90.19°K	22.507		
ΔS_{vap} at 90.19°K = 1631.2/90.19	18.086		(3)
S for vap.	40.593		
S° spect. for gas	40.684		
		S°−S = .091 E. U.	

Berthelot correction, S°−S = .17 E. U.

Entropy correction using P and P^2 terms of present correlation

$(S°-S)_{90.19°K} = .100\ P + .0048\ P^2$ or .105 E. U. for P = 1 atm

(1) Giauque and Johnston
(2) Hoge, Table 9.50
(3) Furukawa and McCoskey

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.10 Molecular Oxygen (Ideal Gas State)

July 1949

Specific Heat, Enthalpy, Entropy

$C_p^\circ/R, \quad (H^\circ - E_0^\circ)/RT_0, \quad S^\circ/R$

compiled by Harold W. Woolley

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards. This table is also available on IBM punched cards.

°K	$\frac{C_p^\circ}{R}$	Δ	$\frac{(H^\circ - E_0^\circ)}{RT_0}$	Δ	$\frac{S^\circ}{R}$	Δ	°R
10	3.5423	−278	0.1222	1291	12.7490	24447	18
20	3.5145	− 68	0.2513	1285	15.1937	14043	36
30	3.5077	− 33	0.3798	1283	16.5980	10276	54
40	3.5044	− 15	0.5081	1283	17.6256	7860	72
50	3.5029	− 6	0.6364	1282	18.4116	6345	90
60	3.5023	− 4	0.7646	1282	19.0461	5376	108
70	3.5019	− 3	0.8928	1282	19.5837	4698	126
80	3.5016	− 1	1.0210	1282	20.0535	4121	144
90	3.5015	− 1	1.1492	1282	20.4656	3692	162
100	3.5014	− 1	1.2774	1282	20.8348	3336	180
110	3.5013	0	1.4056	1281	21.1684	3048	198
120	3.5013	− 1	1.5337	1282	21.4732	2802	216
130	3.5012	+ 1	1.6619	1282	21.7534	2595	234
140	3.5013	0	1.7901	1282	22.0129	2416	252
150	3.5013	+ 2	1.9183	1281	22.2545	2259	270
160	3.5015	2	2.0464	1282	22.4804	2123	288
170	3.5017	3	2.1746	1282	22.6927	2002	306
180	3.5020	5	2.3028	1282	22.8929	1894	324
190	3.5025	7	2.4310	1283	23.0823	1796	342
200	3.5032	10	2.5593	1282	23.2619	1710	360
210	3.5042	14	2.6875	1283	23.4329	1630	378
220	3.5056	17	2.8158	1284	23.5959	1559	396
230	3.5073	22	2.9442	1284	23.7518	1493	414
240	3.5095	27	3.0726	1286	23.9011	1433	432
250	3.5122	33	3.2012	1286	24.0444	1378	450
260	3.5155	38	3.3298	1288	24.1822	1328	468
270	3.5193	45	3.4586	1289	24.3150	1280	486
280	3.5238	50	3.5875	1291	24.4430	1238	504
290	3.5288	56	3.7166	1293	24.5668	1197	522
300	3.5344	63	3.8459	1295	24.6865	1160	540
310	3.5407	69	3.9754	1297	24.8025	1125	558
320	3.5476	75	4.1051	1300	24.9150	1093	576
330	3.5551	80	4.2351	1303	25.0243	1062	594
340	3.5631	86	4.3654	1306	25.1305	1035	612
350	3.5717	90	4.4960	1309	25.2340	1007	630
360	3.5807	95	4.6269	1313	25.3347	982	648
370	3.5902	100	4.7582	1316	25.4329	959	666
380	3.6002	103	4.8898	1320	25.5288	936	684
390	3.6105	107	5.0218	1324	25.6224	916	702
400	3.6212		5.1542		25.7140		720

°K	$\frac{C_p^\circ}{R}$	Δ	$\frac{(H^\circ - E_0^\circ)}{RT_0}$	Δ	$\frac{S^\circ}{R}$	Δ	°R
400	3.6212	110	5.1542	1327	25.7140	896	720
410	3.6322	113	5.2869	1332	25.8036	876	738
420	3.6435	115	5.4201	1336	25.8912	859	756
430	3.6550	118	5.5537	1340	25.9771	841	774
440	3.6668	119	5.6877	1345	26.0612	826	792
450	3.6787	120	5.8222	1349	26.1438	810	810
460	3.6907	122	5.9571	1353	26.2248	795	828
470	3.7029	122	6.0924	1358	26.3043	780	846
480	3.7151	123	6.2282	1362	26.3823	768	864
490	3.7274	122	6.3644	1367	26.4591	754	882
500	3.7396	124	6.5011	1371	26.5345	742	900
510	3.7520	123	6.6382	1376	26.6087	730	918
520	3.7643	122	6.7758	1380	26.6817	718	936
530	3.7765	122	6.9138	1385	26.7535	707	954
540	3.7887	121	7.0523	1389	26.8242	696	972
550	3.8008	121	7.1912	1394	26.8938	686	990
560	3.8129	119	7.3306	1398	26.9624	676	1008
570	3.8248	118	7.4704	1402	27.0300	666	1026
580	3.8366	117	7.6106	1407	27.0966	657	1044
590	3.8483	116	7.7513	1411	27.1623	648	1062
600	3.8599	114	7.8924	1415	27.2271	639	1080
610	3.8713	113	8.0339	1419	27.2910	630	1098
620	3.8826	111	8.1758	1423	27.3540	622	1116
630	3.8937	110	8.3181	1428	27.4162	614	1134
640	3.9047	108	8.4609	1431	27.4776	607	1152
650	3.9155	107	8.6040	1436	27.5383	598	1170
660	3.9262	105	8.7476	1439	27.5981	591	1188
670	3.9367	103	8.8915	1443	27.6572	584	1206
680	3.9470	101	9.0358	1447	27.7156	577	1224
690	3.9571	101	9.1805	1450	27.7733	570	1242
700	3.9672	98	9.3255	1454	27.8303	564	1260
710	3.9770	96	9.4709	1458	27.8867	557	1278
720	3.9866	95	9.6167	1461	27.9424	550	1296
730	3.9961	93	9.7628	1465	27.9974	545	1314
740	4.0054	91	9.9093	1468	28.0519	538	1332
750	4.0145	90	10.0561	1471	28.1057	532	1350
760	4.0235	88	10.2032	1475	28.1589	527	1368
770	4.0323	86	10.3507	1478	28.2116	521	1386
780	4.0409	85	10.4985	1481	28.2637	515	1404
790	4.0494	83	10.6466	1484	28.3152	510	1422
800	4.0577		10.7950		28.3662		1440

CONVERSION FACTORS

To Convert Tabulated Values of	To The Dimensions Indicated Below	Multiply By
$\frac{C_p^\circ}{R}$, $\frac{S^\circ}{R}$	cal mole^{-1} $^\circ K^{-1}$ (or $^\circ C^{-1}$)	1.98719
	cal g^{-1} $^\circ K^{-1}$ (or $^\circ C^{-1}$)	0.0620996
	joules g^{-1} $^\circ K^{-1}$ (or $^\circ C^{-1}$)	0.259825
	Btu (lb mole)$^{-1}$ $^\circ R^{-1}$ (or $^\circ F^{-1}$)	1.98588
	Btu lb^{-1} $^\circ R^{-1}$ (or $^\circ F^{-1}$)	0.0620587

°K	$\frac{C_p^\circ}{R}$	Δ	$\frac{(H^\circ - E_0^\circ)}{RT_0}$	Δ	$\frac{S^\circ}{R}$	Δ	°R
800	4.0577	393	10.7950	7464	28.3662	2472	1440
850	4.0970	357	11.5414	7532	28.6134	2352	1530
900	4.1327	325	12.2946	7595	28.8486	2243	1620
950	4.1652	296	13.0541	7652	29.0729	2145	1710
1000	4.1948	271	13.8193	7703	29.2874	2053	1800
1050	4.2219	250	14.5896	7751	29.4927	1970	1890
1100	4.2469	229	15.3647	7795	29.6897	1893	1980
1150	4.2698	214	16.1442	7836	29.8790	1821	2070
1200	4.2912	200	16.9278	7873	30.0611	1756	2160
1250	4.3112	188	17.7151	7908	30.2367	1695	2250
1300	4.3300	179	18.5059	7943	30.4062	1638	2340
1350	4.3479	172	19.3002	7974	30.5700	1584	2430
1400	4.3651	164	20.0976	8005	30.7284	1535	2520
1450	4.3815	160	20.8981	8035	30.8819	1488	2610
1500	4.3975	155	21.7016	8064	31.0307	1444	2700
1550	4.4130	152	22.5080	8091	31.1751	1404	2790
1600	4.4282	149	23.3171	8119	31.3155	1364	2880
1650	4.4431	147	24.1290	8147	31.4519	1329	2970
1700	4.4578	146	24.9437	8172	31.5848	1294	3060
1750	4.4724	144	25.7609	8200	31.7142	1262	3150
1800	4.4868	143	26.5809	8227	31.8404	1232	3240
1850	4.5011	142	27.4036	8252	31.9636	1202	3330
1900	4.5153	142	28.2288	8277	32.0838	1175	3420
1950	4.5295	141	29.0565	8304	32.2013	1148	3510
2000	4.5436	140	29.8869	8329	32.3161	1124	3600
2050	4.5576	139	30.7198	8356	32.4285	1100	3690
2100	4.5715	139	31.5554	8381	32.5385	1077	3780
2150	4.5854	139	32.3935	8406	32.6462	1056	3870
2200	4.5993	137	33.2341	8430	32.7518	1035	3960
2250	4.6130	137	34.0771	8456	32.8553	1015	4050
2300	4.6267	137	34.9227	8482	32.9568	997	4140
2350	4.6404	136	35.7709	8508	33.0565	978	4230
2400	4.6540	134	36.6217	8530	33.1543	961	4320
2450	4.6674	134	37.4747	8555	33.2504	945	4410
2500	4.6808	132	38.3302	8580	33.3449	928	4500
2550	4.6940	131	39.1882	8605	33.4377	912	4590
2600	4.7071	129	40.0487	8627	33.5289	898	4680
2650	4.7200	128	40.9114	8651	33.6187	884	4770
2700	4.7328	126	41.7765	8675	33.7071	869	4860
2750	4.7454	125	42.6440	8698	33.7940	856	4950
2800	4.7579	124	43.5138	8720	33.8796	844	5040
2850	4.7703	121	44.3858	8743	33.9640	830	5130
2900	4.7824		45.2601		34.0470		5220

°K	$\frac{C_p^\circ}{R}$	Δ	$\frac{(H^\circ - E_0^\circ)}{RT_0}$	Δ	$\frac{S^\circ}{R}$	Δ	°R
2900	4.7824	120	45.2601	8765	34.0470	819	5220
2950	4.7944	118	46.1366	8786	34.1289	807	5310
3000	4.8062	115	47.0152	8809	34.2096	795	5400
3050	4.8177	114	47.8961	8829	34.2891	784	5490
3100	4.8291	111	48.7790	8850	34.3675	774	5580
3150	4.8402	110	49.6640	8869	34.4449	763	5670
3200	4.8512	107	50.5509	8889	34.5212	753	5760
3250	4.8619	105	51.4398	8909	34.5965	743	5850
3300	4.8724	103	52.3307	8929	34.6708	734	5940
3350	4.8827	102	53.2236	8947	34.7442	724	6030
3400	4.8929	99	54.1183	8965	34.8166	715	6120
3450	4.9028	97	55.0148	8982	34.8881	706	6210
3500	4.9125	95	55.9130	9002	34.9587	698	6300
3550	4.9220	92	56.8132	9018	35.0285	689	6390
3600	4.9312	91	57.7150	9033	35.0974	680	6480
3650	4.9403	88	58.6183	9050	35.1654	673	6570
3700	4.9491	87	59.5233	9068	35.2327	665	6660
3750	4.9578	84	60.4301	9083	35.2992	657	6750
3800	4.9662	82	61.3384	9098	35.3649	650	6840
3850	4.9744	81	62.2482	9112	35.4299	642	6930
3900	4.9825	78	63.1594	9127	35.4941	635	7020
3950	4.9903	76	64.0721	9141	35.5576	628	7110
4000	4.9979	75	64.9862	9160	35.6204	622	7200
4050	5.0054	72	65.9022	9171	35.6826	615	7290
4100	5.0126	71	66.8193	9178	35.7441	608	7380
4150	5.0197	68	67.7371	9190	35.8049	601	7470
4200	5.0265	67	68.6561	9204	35.8650	595	7560
4250	5.0332	65	69.5765	9218	35.9245	590	7650
4300	5.0397	63	70.4983	9234	35.9835	583	7740
4350	5.0460	61	71.4217	9244	36.0418	577	7830
4400	5.0521	59	72.3461	9254	36.0995	571	7920
4450	5.0580	58	73.2715	9261	36.1566	566	8010
4500	5.0638	55	74.1976	9270	36.2132	559	8100
4550	5.0693	53	75.1246	9282	36.2691	555	8190
4600	5.0746	51	76.0528	9299	36.3246	548	8280
4650	5.0797	50	76.9827	9308	36.3794	544	8370
4700	5.0847	49	77.9135	9310	36.4338	538	8460
4750	5.0896	47	78.8445	9315	36.4876	534	8550
4800	5.0943	44	79.7760	9326	36.5410	528	8640
4850	5.0987	41	80.7086	9337	36.5938	523	8730
4900	5.1028	40	81.6423	9347	36.6461	519	8820
4950	5.1068	41	82.5770	9352	36.6980	513	8910
5000	5.1109		83.5122		36.7493		9000

CONVERSION FACTORS

To Convert Tabulated Values of	To The Dimensions Indicated Below	Multiply By
$\frac{H^\circ - E_0^\circ}{RT_0}$	cal $mole^{-1}$	542.821
	cal g^{-1}	16.9632
	joules g^{-1}	70.9742
	Btu $(lb\ mole)^{-1}$	976.437
	Btu lb^{-1}	30.5137

MOLECULAR OXYGEN

THE PROPERTIES TABULATED

The thermodynamic properties (Specific Heat, Entropy, and Enthalpy) of molecular oxygen in the ideal gas state are given in dimensionless form. The properties C_p^o/R, $(H^o-E_0^o)/RT_0$., and S^o/R are tabulated as functions of temperature, which is given in degrees K and in degrees R. The values are based on the tables given by Woolley [1] and are for the normal isotopic mixture.

RELIABILITY OF THE TABLES

The calculations for O_2 are based in general on rather precise spectroscopic data, except for some of the high energy states, so that the tabulated values should be reliable to the next to the last digit given except at temperatures near 5000°K, where the uncertainties may approach 0.003 in C_p^o/R, 0.0005 in S^o/R, and 0.005 in $(H^o-E_0^o)/RT_0$.

The values of the thermodynamic properties given in this table should not be used for the actual gas at those elevated temperatures and lowered pressures at which an appreciable part of the gas is dissociated. At a pressure of one atmosphere and a temperature of 3600°K the enthalpy of the actual partially dissociated oxygen is approximately twice as great as that of the pure molecular form tabulated. At 0.01 atmosphere a similar condition is attained at 2800°K. More extensive information on the thermodynamic properties of partially dissociated oxygen will be found in table 9.2 of this series.

INTERPOLATION

The validity of linear interpolation varies throughout this table The error does not exceed one eighth of the second difference which can be obtained by inspection from the first differences tabulated. Where more precise interpolated values are desired, a four point Lagrangian interpolation may be used [2].

CONVERSION FACTORS

The functions in this table have been expressed in dimensionless form in order that they may be converted readily to any system of units. Conversion factors are listed for the most often used units. For values of R and RT_0 not listed in this table and for other conversion factors see Tables ~~1.20 and~~ 1.30 of this series. The symbol R denotes the gas constant and T_0 is 273.16° Kelvin. The calorie used in the conversion factors is the thermochemical calorie and unless otherwise specified, the mole is the gram - mole.

REFERENCES:

[1]. H. W. Woolley, Thermodynamic functions of molecular oxygen in the ideal gas state, J. Research NBS 40, 163 (1948)RP1864.

[2]. Tables of Lagrangian Interpolation Coefficients (Columbia University Press, New York, N.Y., 1944).

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.11 Molecular Oxygen

July 1950

Free Energy

$$-(F^{\circ}-E_0^{\circ})/RT$$

compiled by Harold W. Woolley

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards. This table is also available on IBM punched cards.

°K	$-\left(\frac{F^\circ - E_0^\circ}{RT}\right)$	Δ	°R	°K	$-\left(\frac{F^\circ - E_0^\circ}{RT}\right)$	Δ	°R
				400	22.194		720
						87	
10	9.411		18	410	22.281		738
		2350				85	
20	11.761		36	420	22.366		756
		1379				83	
30	13.140		54	430	22.449		774
		1016				81	
40	14.156		72	440	22.530		792
		779				80	
50	14.935		90	450	22.610		810
		630				77	
60	15.565		108	460	22.687		828
		535				77	
70	16.100		126	470	22.764		846
		467				74	
80	16.567		144	480	22.838		864
		411				73	
90	16.978		162	490	22.911		882
		368				72	
100	17.346		180	500	22.983		900
		332				70	
110	17.678		198	510	23.053		918
		304				69	
120	17.982		216	520	23.122		936
		279				68	
130	18.261		234	530	23.190		954
		259				67	
140	18.520		252	540	23.257		972
		241				65	
150	18.761		270	550	23.322		990
		226				65	
160	18.987		288	560	23.387		1008
		212				63	
170	19.199		306	570	23.450		1026
		199				62	
180	19.398		324	580	23.512		1044
		189				62	
190	19.587		342	590	23.574		1062
		179				60	
200	19.766		360	600	23.634		1080
		171				59	
210	19.937		378	610	23.693		1098
		163				59	
220	20.100		396	620	23.752		1116
		155				58	
230	20.255		414	630	23.810		1134
		149				56	
240	20.404		432	640	23.866		1152
		143				57	
250	20.547		450	650	23.923		1170
		137				55	
260	20.684		468	660	23.978		1188
		132				54	
270	20.816		486	670	24.032		1206
		127				54	
280	20.943		504	680	24.086		1224
		123				53	
290	21.066		522	690	24.139		1242
		119				52	
300	21.185		540	700	24.191		1260
		115				52	
310	21.300		558	710	24.243		1278
		111				51	
320	21.411		576	720	24.294		1296
		108				50	
330	21.519		594	730	24.344		1314
		104				50	
340	21.623		612	740	24.394		1332
		102				49	
350	21.725		630	750	24.443		1350
		99				49	
360	21.824		648	760	24.492		1368
		96				48	
370	21.920		666	770	24.540		1386
		94				47	
380	22.014		684	780	24.587		1404
		91				47	
390	22.105		702	790	24.634		1422
		89				46	
400	22.194		720	800	24.680		1440

°K	$\frac{-(F^\circ - E_0^\circ)}{RT}$	Δ	°R
800	24.680	224	1440
850	24.904	213	1530
900	25.117	202	1620
950	25.319	194	1710
1000	25.513	184	1800
1050	25.697	177	1890
1100	25.874	170	1980
1150	26.044	164	2070
1200	26.208	158	2160
1250	26.366	152	2250
1300	26.518	147	2340
1350	26.665	142	2430
1400	26.807	138	2520
1450	26.945	134	2610
1500	27.079	130	2700
1550	27.209	126	2790
1600	27.335	122	2880
1650	27.457	120	2970
1700	27.577	116	3060
1750	27.693	114	3150
1800	27.807	110	3240
1850	27.917	108	3330
1900	28.025	106	3420
1950	28.131	103	3510
2000	28.234	101	3600
2050	28.335	99	3690
2100	28.434	97	3780
2150	28.531	94	3870
2200	28.625	93	3960
2250	28.718	91	4050
2300	28.809	90	4140
2350	28.899	87	4230
2400	28.986	86	4320
2450	29.072	85	4410
2500	29.157	83	4500
2550	29.240	81	4590
2600	29.321	81	4680
2650	29.402	79	4770
2700	29.481	77	4860
2750	29.558	77	4950
2800	29.635	75	5040
2850	29.710	74	5130
2900	29.784	73	5220
2950	29.857	72	5310
3000	29.929		5400

°K	$\frac{-(F^\circ - E_0^\circ)}{RT}$	Δ	°R
3000	29.929	71	5400
3050	30.000	69	5490
3100	30.069	69	5580
3150	30.138	68	5670
3200	30.206	67	5760
3250	30.273	66	5850
3300	30.339	65	5940
3350	30.404	65	6030
3400	30.469	63	6120
3450	30.532	63	6210
3500	30.595	62	6300
3550	30.657	61	6390
3600	30.718	61	6480
3650	30.779	59	6570
3700	30.838	59	6660
3750	30.897	59	6750
3800	30.956	57	6840
3850	31.013	57	6930
3900	31.070	57	7020
3950	31.127	56	7110
4000	31.183	55	7200
4050	31.238	54	7290
4100	31.292	54	7380
4150	31.346	54	7470
4200	31.400	53	7560
4250	31.453	52	7650
4300	31.505	52	7740
4350	31.557	51	7830
4400	31.608	51	7920
4450	31.659	50	8010
4500	31.709	50	8100
4550	31.759	49	8190
4600	31.808	49	8280
4650	31.857	49	8370
4700	31.906	48	8460
4750	31.954	47	8550
4800	32.001	47	8640
4850	32.048	47	8730
4900	32.095	46	8820
4950	32.141	46	8910
5000	32.187		9000

TABLE 9.11 MOLECULAR OXYGEN: FREE ENERGY FUNCTION

THE PROPERTY TABULATED

In this table a function of the Gibbs free energy, F°, that is convenient in the calculation of chemical equilibrium is presented for molecular oxygen in the ideal gas state. The function is the dimensionless quantity $-(F^\circ - E_0^\circ)/RT$, where E_0° is the energy of the ideal gas at 0°K, R is the universal gas constant and T is the absolute temperature. The negative free energy function is tabulated as a function of the temperature which is given in degrees Kelvin and degrees Rankine. The values are consistent with the values of enthalpy and entropy given in Table 9.10 of this series, and with those of reference [1], according to the definition of Gibbs free energy, $F = H - TS$.

RELIABILITY OF THE TABLE

The values given are considered to be very reliable, being uncertain by less than one unit in the third decimal place up to the highest temperatures.

INTERPOLATION

The validity of linear interpolation varies throughout this table depending upon the number of figures desired. The error produced by linear interpolation does not exceed one-eighth of the second difference. Where more precise values are desired, a four-point Lagrangian interpolation may be used [2].

CONVERSION FACTORS, CONSTANTS, AND DEFINITIONS OF SYMBOLS

The function in this table has been expressed in dimensionless form. In order that it may be converted readily to any system of units, conversion factors are listed for the frequently used units. The following constants have been used in this compilation; the universal gas constant R = 1.98719 cal mole^{-1} deg^{-1}; the molecular weight of oxygen = 32.000; the thermochemical calorie = 4.1840 abs. joules. Unless otherwise specified the mole is the gram-mole. For other conversion factors, constants, and definitions see Table 1.30 of this series.

CONVERSION FACTORS

To Convert Tabulated Value of	To	Having the Dimensions Indicated Below	Multiply By
$-(F^\circ - E_0^\circ)/RT$	$-(F^\circ - E_0^\circ)/T$	cal mole^{-1} °K^{-1} (or °C^{-1})	1.98719
		cal g^{-1} °K^{-1} (or °C^{-1})	0.0620996
		joules g^{-1} °K^{-1} (or °C^{-1})	0.259825
		Btu (lb mole)$^{-1}$ °R^{-1} (or °F^{-1})	1.98588
		Btu lb^{-1} °R^{-1} (or °F^{-1})	0.0620587

REFERENCES

[1] Harold W. Woolley, Thermodynamic functions for molecular oxygen in the ideal gas state, J. Research NBS 40, 163 (1948) RP1864.

[2] "Tables of Lagrangian Interpolation Coefficients", Columbia University Press, New York, 1944.

☆U. S. GOVERNMENT PRINTING OFFICE : 1950 O - 894645

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 10.10 Atomic Oxygen (Ideal Gas State)

July 1950

Specific Heat, Enthalpy, Entropy

$C_p^\circ/R,\ (H^\circ - E_0^\circ)/RT_0,\ S^\circ/R$

compiled by Harold W. Woolley

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards. This table is also available on IBM punched cards.

°K	C_p°/R	Δ	$(H^\circ - E_0^\circ)/RT_0$	Δ	S°/R	Δ	°R
10	2.5000	9	0.09152	9153	10.3601	17330	18
20	2.5009	171	0.18305	9177	12.0931	10162	36
30	2.5180	512	0.27482	9302	13.1093	7306	54
40	2.5692	726	0.36784	9536	13.8399	5810	72
50	2.6418	724	0.46320	9806	14.4209	4881	90
60	2.7142	589	0.56126	10049	14.9090	4231	108
70	2.7731	414	0.66175	10233	15.3321	3732	126
80	2.8145	250	0.76408	10354	15.7053	3331	144
90	2.8395	115	0.86762	10420	16.0384	2998	162
100	2.8510	13	0.97182	1044	16.3382	2719	180
110	2.8523	− 54	1.0762	1044	16.6101	2480	198
120	2.8469	−100	1.1806	1040	16.8581	2275	216
130	2.8369	−131	1.2846	1036	17.0856	2098	234
140	2.8238	−148	1.3882	1032	17.2954	1943	252
150	2.8090	−156	1.4914	1025	17.4897	1808	270
160	2.7934	−157	1.5939	1020	17.6705	1689	288
170	2.7777	−153	1.6959	1014	17.8394	1583	306
180	2.7624	−146	1.7973	1008	17.9977	1490	324
190	2.7478	−138	1.8981	1004	18.1467	1406	342
200	2.7340	−134	1.9985	999	18.2873	1327	360
210	2.7206	−125	2.0984	994	18.4200	1262	378
220	2.7081	−117	2.1978	989	18.5462	1202	396
230	2.6964	−109	2.2967	985	18.6664	1147	414
240	2.6855	−102	2.3952	981	18.7811	1096	432
250	2.6753	− 95	2.4933	978	18.8907	1046	450
260	2.6658	− 89	2.5911	974	18.9953	1004	468
270	2.6569	− 83	2.6885	971	19.0957	966	486
280	2.6486	− 77	2.7856	968	19.1923	928	504
290	2.6409	− 71	2.8824	965	19.2851	895	522
300	2.6338	− 67	2.9789	963	19.3746	861	540
310	2.6271	− 22	3.0752	961	19.4607	833	558
320	2.6209	− 58	3.1713	958	19.5440	806	576
330	2.6151	− 54	3.2671	957	19.6246	780	594
340	2.6097	− 51	3.3628	954	19.7026	756	612
350	2.6046	− 48	3.4582	953	19.7782	733	630
360	2.5998	− 44	3.5535	951	19.8515	712	648
370	2.5954	− 42	3.6486	949	19.9227	691	666
380	2.5912	− 39	3.7435	948	19.9918	674	684
390	2.5873	− 37	3.8383	947	20.0592	654	702
400	2.5836		3.9330		20.1246		720

°K	C_p°/R	Δ	$(H^\circ - E_0^\circ)/RT_0$	Δ	S°/R	Δ	°R
400	2.5836	− 34	3.9330	945	20.1246	638	720
410	2.5802	− 33	4.0275	944	20.1884	621	738
420	2.5769	− 31	4.1219	943	20.2505	605	756
430	2.5738	− 29	4.2162	941	20.3110	592	774
440	2.5709	− 28	4.3103	941	20.3702	578	792
450	2.5681	− 26	4.4044	939	20.4280	563	810
460	2.5655	− 25	4.4983	939	20.4843	553	828
470	2.5630	− 23	4.5922	938	20.5396	539	846
480	2.5607	− 22	4.6860	938	20.5935	529	864
490	2.5585	− 20	4.7798	936	20.6464	516	882
500	2.5565	− 20	4.8734	936	20.6980	507	900
510	2.5545	− 18	4.9670	935	20.7487	495	918
520	2.5527	− 18	5.0605	934	20.7982	487	936
530	2.5509	− 17	5.1539	933	20.8469	476	954
540	2.5492	− 16	5.2472	933	20.8945	467	972
550	2.5476	− 15	5.3405	932	20.9412	459	990
560	2.5461	− 15	5.4337	932	20.9871	451	1008
570	2.5446	− 14	5.5269	931	21.0322	442	1026
580	2.5432	− 13	5.6200	931	21.0764	435	1044
590	2.5419	− 13	5.7131	930	21.1199	426	1062
600	2.5406	− 12	5.8061	930	21.1625	420	1080
610	2.5394	− 12	5.8991	930	21.2045	412	1098
620	2.5382	− 11	5.9921	929	21.2457	406	1116
630	2.5371	− 11	6.0850	928	21.2863	399	1134
640	2.5360	− 10	6.1778	928	21.3262	394	1152
650	2.5350	− 10	6.2706	928	21.3656	387	1170
660	2.5340	− 9	6.3634	928	21.4043	381	1188
670	2.5331	− 10	6.4562	927	21.4424	375	1206
680	2.5321	− 9	6.5489	927	21.4799	370	1224
690	2.5312	− 8	6.6416	927	21.5169	365	1242
700	2.5304	− 8	6.7343	926	21.5534	359	1260
710	2.5296	− 8	6.8269	926	21.5893	353	1278
720	2.5288	− 7	6.9195	925	21.6246	349	1296
730	2.5281	− 7	7.0120	926	21.6595	344	1314
740	2.5274	− 7	7.1046	925	21.6939	339	1332
750	2.5267	− 6	7.1971	924	21.7278	335	1350
760	2.5261	− 7	7.2895	925	21.7613	330	1368
770	2.5254	− 6	7.3820	924	21.7943	326	1386
780	2.5248	− 6	7.4744	924	21.8269	321	1404
790	2.5242	− 5	7.5668	924	21.8590	318	1422
800	2.5237		7.6592		21.8908		1440

CONVERSION FACTORS

To Convert Tabulated Value of	To	Having the Dimensions Indicated Below	Multiply By
C_p°/R, S°/R	C_p°, S°	cal mole^{-1} °K^{-1} (or °C^{-1})	1.98719
		cal g^{-1} °K^{-1} (or °C^{-1})	0.124199
		joules g^{-1} °K^{-1} (or °C^{-1})	0.519650
		Btu (lb mole)$^{-1}$ °R^{1} (or °F^{-1})	1.98588
		Btu lb^{-1} °R^{-1} (or °F^{-1})	0.124118

°K	C_p°/R	Δ	$(H^\circ - E_0^\circ)/RT_0$	Δ	S°/R	Δ	°R
800	2.5237	-26	7.6592	4618	21.8908	1529	1440
850	2.5211	-22	8.1210	4614	22.0437	1441	1530
900	2.5189	-18	8.5824	4608	22.1878	1361	1620
950	2.5171	-16	9.0432	4605	22.3239	1291	1710
1000	2.5155	-14	9.5037	4603	22.4530	1226	1800
1050	2.5141	-12	9.9640	4601	22.5756	1169	1890
1100	2.5129	-11	10.4241	4599	22.6925	1117	1980
1150	2.5118	-10	10.8840	4597	22.8042	1069	2070
1200	2.5108	-8	11.3437	4595	22.9111	1025	2160
1250	2.5100	-7	11.8032	4594	23.0136	985	2250
1300	2.5093	-7	12.2626	4593	23.1121	947	2340
1350	2.5086	-6	12.7219	4592	23.2068	912	2430
1400	2.5080	-6	13.1811	4591	23.2980	880	2520
1450	2.5074	-4	13.6402	4589	23.3860	850	2610
1500	2.5070	-4	14.0991	4588	23.4710	822	2700
1550	2.5066	-3	14.5579	4588	23.5532	797	2790
1600	2.5063	-3	15.0167	4588	23.6329	772	2880
1650	2.5060	-3	15.4755	4587	23.7101	748	2970
1700	2.5057	-3	15.9342	4585	23.7849	726	3060
1750	2.5054	-2	16.3927	4585	23.8575	706	3150
1800	2.5052	-1	16.8512	4585	23.9281	686	3240
1850	2.5051	-2	17.3097	4586	23.9967	668	3330
1900	2.5049	0	17.7683	4585	24.0635	651	3420
1950	2.5049	-1	18.2268	4585	24.1286	634	3510
2000	2.5048	1	18.6853	4584	24.1920	618	3600
2050	2.5049	0	19.1437	4585	24.2538	604	3690
2100	2.5049	2	19.6022	4586	24.3142	589	3780
2150	2.5051	2	20.0608	4587	24.3731	576	3870
2200	2.5053	2	20.5195	4587	24.4307	563	3960
2250	2.5055	3	20.9782	4587	24.4870	551	4050
2300	2.5058	4	21.4369	4587	24.5421	539	4140
2350	2.5062	5	21.8956	4587	24.5960	528	4230
2400	2.5067	5	22.3543	4588	24.6488	517	4320
2450	2.5072	6	22.8131	4588	24.7005	506	4410
2500	2.5078	6	23.2719	4591	24.7511	497	4500
2550	2.5084	8	23.7310	4592	24.8008	487	4590
2600	2.5092	8	24.1902	4593	24.8495	478	4680
2650	2.5100	9	24.6495	4596	24.8973	469	4770
2700	2.5109	10	25.1091	4597	24.9442	461	4860
2750	2.5119	11	25.5688	4599	24.9903	453	4950
2800	2.5130	12	26.0287	4601	25.0356	444	5040
2850	2.5142	13	26.4888	4603	25.0800	438	5130
2900	2.5155	13	26.9491	4606	25.1238	430	5220
2950	2.5168	14	27.4097	4608	25.1668	423	5310
3000	2.5182		27.8705		25.2091		5400

°K	C_p°/R	Δ	$(H^\circ - E_0^\circ)/RT_0$	Δ	S°/R	Δ	°R
3000	2.5182	15	27.8705	4611	25.2091	417	5400
3050	2.5197	16	28.3316	4615	25.2508	410	5490
3100	2.5213	16	28.7931	4617	25.2918	403	5580
3150	2.5229	18	29.2548	4620	25.3321	398	5670
3200	2.5247	18	29.7168	4624	25.3719	392	5760
3250	2.5265	19	30.1792	4626	25.4111	386	5850
3300	2.5284	20	30.6418	4629	25.4497	380	5940
3350	2.5304	21	31.1047	4633	25.4877	375	6030
3400	2.5325	21	31.5680	4636	25.5252	369	6120
3450	2.5346	22	32.0316	4640	25.5621	365	6210
3500	2.5368	23	32.4956	4645	25.5986	360	6300
3550	2.5391	23	32.9601	4650	25.6346	355	6390
3600	2.5414	24	33.4251	4655	25.6701	351	6480
3650	2.5438	25	33.8906	4659	25.7052	346	6570
3700	2.5463	25	34.3565	4664	25.7398	342	6660
3750	2.5488	25	34.8229	4668	25.7740	338	6750
3800	2.5513	26	35.2897	4672	25.8078	333	6840
3850	2.5539	27	35.7569	4677	25.8411	330	6930
3900	2.5566	27	36.2246	4681	25.8741	326	7020
3950	2.5593	28	36.6927	4687	25.9067	322	7110
4000	2.5621	28	37.1614	4692	25.9389	319	7200
4050	2.5649	28	37.6306	4698	25.9708	314	7290
4100	2.5677	29	38.1004	4703	26.0022	312	7380
4150	2.5706	29	38.5707	4709	26.0334	308	7470
4200	2.5735	29	39.0416	4714	26.0642	305	7560
4250	2.5764	30	39.5130	4719	26.0947	302	7650
4300	2.5794	30	39.9849	4724	26.1249	298	7740
4350	2.5824	29	40.4573	4730	26.1547	295	7830
4400	2.5853	30	40.9303	4735	26.1842	293	7920
4450	2.5883	30	41.4038	4741	26.2135	289	8010
4500	2.5913	31	41.8779	4747	26.2424	286	8100
4550	2.5944	30	42.3526	4752	26.2710	284	8190
4600	2.5974	31	42.8278	4758	26.2994	281	8280
4650	2.6005	31	43.3036	4764	26.3275	278	8370
4700	2.6036	30	43.7800	4769	26.3553	276	8460
4750	2.6066	31	44.2569	4774	26.3829	273	8550
4800	2.6097	31	44.7343	4780	26.4102	271	8640
4850	2.6128	30	45.2123	4784	26.4373	268	8730
4900	2.6158	31	45.6907	4789	26.4641	266	8820
4950	2.6189	30	46.1696	4793	26.4907	263	8910
5000	2.6219		46.6489		26.5170		9000

CONVERSION FACTORS

To Convert Tabulated Value of	To	Having the Dimensions Indicated Below	Multiply By
$(H^\circ - E_0^\circ)/RT_0$	$(H^\circ - E_0^\circ)$	cal mole^{-1}	542.821
		cal g^{-1}	33.9263
		joules g^{-1}	141.948
		Btu (lb mole)$^{-1}$	976.437
		Btu lb^{-1}	61.0273

TABLE 10.10 ATOMIC OXYGEN (IDEAL GAS STATE)

THE PROPERTIES TABULATED

These tables give in dimensionless form as functions of temperature in degrees Kelvin and degrees Rankine, the following thermodynamic properties of atomic oxygen in the ideal gas state: the specific heat at constant pressure, C_p^o; the enthalpy, H^o; and the entropy, S^o. The zero reference point of the enthalpy is taken as the ideal gas internal energy, E_0^o, at absolute zero. The tabulated quantities are made dimensionless by dividing by R or RT_0, where R is the universal gas constant and T_0 is the absolute temperature of the ice point. The tables are based on those given in reference 1 with some extension and subtabulation.

RELIABILITY OF THE TABLE

The values in this table are considered to be very reliable. It appears probable that any inaccuracies introduced in the subtabulation would be of the order of 0.0001.

INTERPOLATION

The validity of linear interpolation varies throughout this table depending upon the number of figures desired. The error produced by linear interpolation does not exceed one-eighth of the second difference. Where more precise values are desired a four-point Lagrangian interpolation may be used [2].

CONVERSION FACTORS, CONSTANTS, AND DEFINITIONS OF SYMBOLS

The functions in this table have been expressed in dimensionless form in order that they may be converted readily to any system of units. Conversion factors are listed for the frequently used units. The following constants have been used in this compilation: the gas constant R = 1.98719 cal mole^{-1} deg^{-1}; the atomic weight of oxygen = 16.0000; T_0 = 273.16 K; the thermochemical calorie = 4.1840 abs. joules. Unless otherwise specified the mole is the gram-mole. For other conversion factors, constants, and definitions see table 1.30 of this series.

REFERENCES

[1] "Selected Values of Chemical Thermodynamic Properties," National Bureau of Standards.

[2] "Tables of Lagrangian Interpolation Coefficients," (Columbia University Press, New York, N.Y., 1944).

U. S. GOVERNMENT PRINTING OFFICE: 1950 O - 887338

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 10.11 Atomic Oxygen

July 1950

Free Energy

$$-(F^{\circ}-E_0^{\circ})/RT$$

compiled by Harold W. Woolley

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards. This table is also available on IBM punched cards.

°K	$-\left(\frac{F^{\circ}-E_0^{\circ}}{RT}\right)$	Δ	°R
10	7.8601	17329	18
20	9.5930	10140	36
30	10.6070	7209	54
40	11.3279	5624	72
50	11.8903	4635	90
60	12.3538	3959	108
70	12.7497	3466	126
80	13.0963	3087	144
90	13.4050	2786	162
100	13.6836	2539	180
110	13.9375	2332	198
120	14.1707	2156	216
130	14.3863	2004	234
140	14.5867	1871	252
150	14.7738	1754	270
160	14.9492	1651	288
170	15.1143	1559	306
180	15.2702	1475	324
190	15.4177	1400	342
200	15.5577	1328	360
210	15.6905	1269	378
220	15.8174	1214	396
230	15.9388	1162	414
240	16.0550	1114	432
250	16.1664	1068	450
260	16.2732	1027	468
270	16.3759	989	486
280	16.4748	954	504
290	16.5702	920	522
300	16.6622	888	540
310	16.7510	859	558
320	16.8369	833	576
330	16.9202	807	594
340	17.0009	783	612
350	17.0792	760	630
360	17.1552	739	648
370	17.2291	718	666
380	17.3009	699	684
390	17.3708	680	702
400	17.4388		720

°K	$-\left(\frac{F^{\circ}-E_0^{\circ}}{RT}\right)$	Δ	°R
400	17.4388	663	720
410	17.5051	646	738
420	17.5697	630	756
430	17.6327	616	774
440	17.6943	601	792
450	17.7544	587	810
460	17.8131	575	828
470	17.8706	561	846
480	17.9267	551	864
490	17.9818	538	882
500	18.0356	527	900
510	18.0883	516	918
520	18.1399	507	936
530	18.1906	496	954
540	18.2402	486	972
550	18.2888	478	990
560	18.3366	469	1008
570	18.3835	460	1026
580	18.4295	453	1044
590	18.4748	444	1062
600	18.5192	436	1080
610	18.5628	430	1098
620	18.6058	422	1116
630	18.6480	415	1134
640	18.6895	408	1152
650	18.7303	403	1170
660	18.7706	396	1188
670	18.8102	390	1206
680	18.8492	384	1224
690	18.8876	379	1242
700	18.9255	372	1260
710	18.9627	368	1278
720	18.9995	361	1296
730	19.0356	357	1314
740	19.0713	352	1332
750	19.1065	347	1350
760	19.1412	343	1368
770	19.1755	337	1386
780	19.2092	334	1404
790	19.2426	329	1422
800	19.2755		1440

°K	$\frac{-(F^\circ - E_0^\circ)}{RT}$	Δ	°R
800	19.2755	1584	1440
850	19.4339	1491	1530
900	19.5830	1407	1620
950	19.7237	1332	1710
1000	19.8569	1266	1800
1050	19.9835	1205	1890
1100	20.1040	1150	1980
1150	20.2190	1099	2070
1200	20.3289	1054	2160
1250	20.4343	1011	2250
1300	20.5354	972	2340
1350	20.6326	934	2430
1400	20.7260	904	2520
1450	20.8164	870	2610
1500	20.9034	842	2700
1550	20.9876	816	2790
1600	21.0692	789	2880
1650	21.1481	764	2970
1700	21.2245	742	3060
1750	21.2987	721	3150
1800	21.3708	701	3240
1850	21.4409	681	3330
1900	21.5090	664	3420
1950	21.5754	646	3510
2000	21.6400	630	3600
2050	21.7030	614	3690
2100	21.7644	600	3780
2150	21.8244	586	3870
2200	21.8830	572	3960
2250	21.9402	560	4050
2300	21.9962	547	4140
2350	22.0509	536	4230
2400	22.1045	524	4320
2450	22.1569	514	4410
2500	22.2083	503	4500
2550	22.2586	494	4590
2600	22.3080	484	4680
2650	22.3564	475	4770
2700	22.4039	466	4860
2750	22.4505	458	4950
2800	22.4963	449	5040
2850	22.5412	441	5130
2900	22.5853	434	5220
2950	22.6287	427	5310
3000	22.6714		5400

°K	$\frac{-(F^\circ - E_0^\circ)}{RT}$	Δ	°R
3000	22.6714	419	5400
3050	22.7133	413	5490
3100	22.7546	406	5580
3150	22.7952	400	5670
3200	22.8352	393	5760
3250	22.8745	387	5850
3300	22.9132	382	5940
3350	22.9514	376	6030
3400	22.9890	370	6120
3450	23.0260	365	6210
3500	23.0625	360	6300
3550	23.0985	354	6390
3600	23.1339	350	6480
3650	23.1689	345	6570
3700	23.2034	340	6660
3750	23.2374	336	6750
3800	23.2710	332	6840
3850	23.3042	327	6930
3900	23.3369	324	7020
3950	23.3693	319	7110
4000	23.4012	315	7200
4050	23.4327	312	7290
4100	23.4639	308	7380
4150	23.4947	304	7470
4200	23.5251	300	7560
4250	23.5551	297	7650
4300	23.5848	294	7740
4350	23.6142	290	7830
4400	23.6432	287	7920
4450	23.6719	284	8010
4500	23.7003	281	8100
4550	23.7284	278	8190
4600	23.7562	275	8280
4650	23.7837	272	8370
4700	23.8109	269	8460
4750	23.8378	267	8550
4800	23.8645	263	8640
4850	23.8908	262	8730
4900	23.9170	259	8820
4950	23.9429	256	8910
5000	23.9685		9000

TABLE 10.11 ATOMIC OXYGEN: FREE ENERGY FUNCTION

THE PROPERTY TABULATED

In this table a function of the Gibbs free energy, F°, that is convenient in the calculation of chemical equilibrium is presented for atomic oxygen in the ideal gas state. The function is the dimensionless quantity $-(F^\circ - E_0^\circ)/RT$, where E_0° is the energy of the ideal gas at 0°K, R is the universal gas constant and T is the absolute temperature. The negative free energy function is tabulated as a function of the temperature which is given in degrees Kelvin and degrees Rankine. The values are consistent with the values of enthalpy and entropy given in Table 10.10 of this series, according to the definition of Gibbs free energy, $F = H - TS$. For use with these tables the recommended value of E_0° for atomic oxygen, referred to the standard state of gaseous molecular oxygen at 0°K is 58.586 kcal/mole. This is based on the value for the heat of formation of atomic oxygen at 0°K [1].

RELIABILITY OF THE TABLE

The tabulated values are thought to be very reliable, probably within 2 units in the last decimal place.

INTERPOLATION

The validity of linear interpolation varies throughout this table depending upon the number of figures desired. The error produced by linear interpolation does not exceed one-eighth of the second difference. Where more precise values are desired, a four-point Lagrangian interpolation may be used [2].

CONVERSION FACTORS, CONSTANTS, AND DEFINITIONS OF SYMBOLS

The function in this table has been expressed in dimensionless form. In order that it may be converted readily to any system of units, conversion factors are listed for the frequently used units. The following constants have been used in this compilation: the gas constant R = 1.98719 cal mole^{-1} deg^{-1}; the atomic weight of oxygen = 16.000; the thermochemical calorie = 4.1840 abs. joules. Unless otherwise specified the mole is the gram-mole. For other conversion factors, ~~constants, and definitions~~ see Table 1.30 of this series.

CONVERSION FACTORS

To Convert Tabulated Value of	To	Having the Dimensions Indicated Below	Multiply By
$-(F^\circ - E_0^\circ)/RT$	$-(F^\circ - E_0^\circ)/T$	cal mole^{-1} °K^{-1} (or °C^{-1})	1.98719
		cal g^{-1} °K^{-1} (or °C^{-1})	0.124199
		joules g^{-1} °K^{-1} (or °C^{-1})	0.519650
		Btu (lb mole)$^{-1}$ °R^{-1} (or °F^{-1})	1.98588
		Btu lb^{-1} °R^{-1} (or °F^{-1})	0.124118

REFERENCES

[1] "Selected Values of Chemical Thermodynamic Properties", National Bureau of Standards.

[2] "Tables of Lagrangian Interpolation Coefficients", Columbia University Press, New York, 1944.

U. S. Department of Commerce National Bureau of Standards

The NBS-NACA Tables of Thermal Properties of Gases

Table 9.18 Density of Molecular Oxygen

ρ/ρ_0

by

Harold W. Woolley

Reissue
1953

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		T °R
100	.02730	-249	.27350	-2499	1.10136	-10220	1.94076	-18306	180
110	.02481	207	.24851	2079	.99916	8461	1.75770	15069	198
120	.02274	175	.22772	1757	.91455	7125	1.60701	12642	216
130	.02099	150	.21015	1505	.84330	6087	1.48059	10772	234
140	.01949	130	.19510	1304	.78243	5261	1.37287	9293	252
150	.01819	113	.18206	1140	.72982	4595	1.27994	8103	270
160	.01706	101	.17066	1005	.68387	4048	1.19891	7130	288
170	.01605	89	.16061	894	.64339	3594	1.12761	6323	306
180	.01516	80	.15167	799	.60745	3211	1.06438	5648	324
190	.01436	71	.14368	719	.57534	2888	1.00790	5075	342
200	.01365	65	.13649	650	.54646	2612	.95715	4586	360
210	.01300	60	.12999	592	.52034	2372	.91129	4165	378
220	.01240	53	.12407	540	.49662	2166	.86964	3799	396
230	.01187	50	.11867	494	.47496	1983	.83165	3480	414
240	.01137	45	.11373	455	.45513	1825	.79685	3199	432
250	.01092	42	.10918	421	.43688	1684	.76486	2952	450
260	.01050	39	.10497	389	.42004	1558	.73534	2732	468
270	.01011	36	.10108	361	.40446	1447	.70802	2536	486
280	.00975	34	.09747	336	.38999	1347	.68266	2360	504
290	.00941	31	.09411	314	.37652	1256	.65906	2202	522
300	.00910	30	.09097	293	.36396	1176	.63704	2060	540
310	.00880	27	.08804	276	.35220	1102	.61644	1930	558
320	.00853	26	.08528	258	.34118	1034	.59714	1812	576
330	.00827	24	.08270	243	.33084	974	.57902	1706	594
340	.00803	23	.08027	230	.32110	919	.56196	1608	612
350	.00780	22	.07797	216	.31191	867	.54588	1518	630
360	.00758	20	.07581	205	.30324	820	.53070	1436	648
370	.00738	20	.07376	194	.29504	777	.51634	1361	666
380	.00718	18	.07182	185	.28727	737	.50273	1290	684
390	.00700	18	.06997	174	.27990	700	.48983	1226	702
400	.00682	16	.06823	167	.27290	666	.47757	1166	720
410	.00666	16	.06656	158	.26624	634	.46591	1110	738
420	.00650	15	.06498	152	.25990	605	.45481	1058	756
430	.00635	15	.06346	144	.25385	577	.44423	1010	774
440	.00620	14	.06202	138	.24808	552	.43413	966	792
450	.00606		.06064		.24256		.42447		810

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		T °R
450	.00606	-13	.06064	-131	.24256	-527	.42447	-923	810
460	.00593	12	.05933	127	.23729	505	.41524	884	828
470	.00581	12	.05806	121	.23224	484	.40640	847	846
480	.00569	12	.5685	116	.22740	464	.39793	813	864
490	.00557	11	.05569	111	.22276	446	.38980	780	882
500	.00546	11	.05458	107	.21830	428	.38200	749	900
510	.00535	10	.05351	103	.21402	412	.37451	721	918
520	.00525	10	.05248	99	.20990	396	.36730	693	936
530	.00515	10	.05149	95	.20594	381	.36037	667	954
540	.00505	9	.05054	92	.20213	368	.35370	643	972
550	.00496	9	.04962	89	.19845	354	.34727	621	990
560	.00487	8	.4873	85	.19491	342	.34106	598	1008
570	.00479	8	.04788	83	.19149	330	.33508	578	1026
580	.00471	8	.04705	80	.18819	319	.32930	558	1044
590	.00463	8	.04625	77	.18500	309	.32372	540	1062
600	.00455	8	.04548	74	.18191	298	.31832	522	1080
610	.00447	7	.04474	73	.17893	289	.31310	505	1098
620	.00440	7	.04401	69	.17604	279	.30805	489	1116
630	.00433	7	.04332	68	.17325	271	.30316	474	1134
640	.00426	6	.04264	66	.17054	262	.29842	459	1152
650	.00420	7	.04198	63	.16792	255	.29383	445	1170
660	.00413	6	.04135	62	.16537	246	.28938	432	1188
670	.00407	6	.04073	60	.16291	240	.28506	419	1206
680	.00401	6	.04013	58	.16051	233	.28087	408	1224
690	.00395	5	.03955	57	.15818	226	.27679	395	1242
700	.00390	6	.03898	54	.15592	219	.27284	384	1260
710	.00384	5	.03844	54	.15373	214	.26900	374	1278
720	.00379	5	.03790	52	.15159	207	.26526	363	1296
730	.00374	5	.03738	50	.14952	202	.26163	354	1314
740	.00369	5	.03688	49	.14750	197	.25809	344	1332
750	.00364	5	.03639	48	.14553	192	.25465	335	1350
760	.00359	5	.03591	47	.14361	186	.25130	326	1368
770	.00354	4	.03544	45	.14175	182	.24804	318	1386
780	.00350	5	.03499	45	.13993	177	.24486	310	1404
790	.00345	4	.03454	43	.13816	173	.24176	302	1422
800	.00341		.03411		.13643		.23874		1440

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		T °R
800	.00341	-20	.03411	-200	.13643	-802	.23874	-1405	1440
850	.00321	18	.03211	179	.12841	714	.22469	1248	1530
900	.00303	16	.03032	159	.12127	638	.21221	1117	1620
950	.00287	14	.02873	144	.11489	574	.20104	1005	1710
1000	.00273	13	.02729	130	.10915	520	.19099	909	1800
1050	.00260	12	.02599	118	.10395	472	.18190	827	1890
1100	.00248	11	.02481	108	.09923	432	.17363	755	1980
1150	.00237	10	.02373	99	.09491	395	.16608	692	2070
1200	.00227	9	.02274	91	.09096	364	.15916	636	2160
1250	.00218	8	.02183	84	.08732	336	.15280	588	2250
1300	.00210	8	.02099	78	.08396	311	.14692	544	2340
1350	.00202	7	.02021	72	.08085	289	.14148	505	2430
1400	.00195	7	.01949	67	.07796	268	.13643	471	2520
1450	.00188	6	.01882	63	.07528	251	.13172	439	2610
1500	.00182	6	.01819	58	.07277	235	.12733	410	2700
1550	.00176	5	.01761	55	.07042	220	.12323	385	2790
1600	.00171	6	.01706	52	.06822	207	.11938	362	2880
1650	.00165	4	.01654	49	.06615	194	.11576	340	2970
1700	.00161	5	.01605	46	.06421	184	.11236	321	3060
1750	.00156	4	.01559	43	.06237	173	.10915	304	3150
1800	.00152	4	.01516	41	.06064	164	.10611	286	3240
1850	.00148	4	.01475	39	.05900	155	.10325	272	3330
1900	.00144	4	.01436	37	.05745	147	.10053	258	3420
1950	.00140	4	.01399	35	.05598	140	.09795	245	3510
2000	.00136	3	.01364	33	.05458	134	.09550	233	3600
2050	.00133	3	.01331	31	.05324	126	.09317	221	3690
2100	.00130	3	.01300	31	.05198	121	.09096	212	3780
2150	.00127	3	.01269	29	.05077	115	.08884	202	3870
2200	.00124	3	.01240	27	.04962	111	.08682	193	3960
2250	.00121	2	.01213	27	.04851	105	.08489	184	4050
2300	.00119		.01186		.04746		.08305		4140

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		T °K
2300	.00119	-3	.01186	-25	.04746	-101	.08305	-177	4140
2350	.00116	2	.01161	24	.04645	97	.08128	169	4230
2400	.00114	3	.01137	23	.04548	93	.07959	163	4320
2450	.00111	2	.01114	22	.04455	89	.07796	156	4410
2500	.00109	2	.01092	22	.04366	85	.07640	149	4500
2550	.00107	2	.01070	20	.04281	83	.07491	144	4590
2600	.00105	2	.01050	20	.04198	79	.07347	139	4680
2650	.00103	2	.01030	19	.04119	76	.07208	133	4770
2700	.00101	2	.01011	19	.04043	74	.07075	129	4860
2750	.00099	2	.00992	17	.03969	71	.06946	124	4950
2800	.00097	1	.00975	17	.03898	68	.06822	120	5040
2850	.00096	2	.00958	17	.03830	66	.06702	115	5130
2900	.00094	2	.00941	16	.03764	64	.06587	112	5220
2950	.00092	1	.00925	15	.03700	62	.06475	108	5310
3000	.00091		.00910		.03638		.06367		5400

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
100	2.79257	-26816							180
110	2.52441	21916	10.755	-1106					198
120	2.30525	18318	9.649	860	-17.86	-1851			216
130	2.12207	15563	8.789	702	16.009	1421	24.0	-24	234
140	1.96644	13398	8.087	591	14.588	1150	21.56	186	252
150	1.83246	11665	7.496	506	13.438	964	19.70	152	270
160	1.71581	10252	6.990	438	12.474	823	18.18	126	288
170	1.61329	9082	6.552	384	11.651	713	16.92	108	306
180	1.52247	8108	6.168	340	10.938	626	15.84	94	324
190	1.44139	7279	5.828	3035	10.312	5536	14.90	827	342
200	1.36860	6575	5.5245	2727	9.7584	4949	14.073	734	360
210	1.30285	5968	5.2518	2463	9.2635	4450	13.339	656	378
220	1.24317	5443	5.0055	2237	8.8185	4026	12.683	592	396
230	1.18874	4984	4.7818	2042	8.4159	3662	12.091	536	414
240	1.13890	4581	4.5776	1872	8.0497	3347	11.555	488	432
250	1.09309	4224	4.3904	1723	7.7150	3072	11.067	447	450
260	1.05085	3909	4.2181	1590	7.4078	2830	10.620	412	468
270	1.01176	3628	4.0591	1473	7.1248	2617	10.208	379	486
280	.97548	3376	3.9118	1369	6.8631	2428	9.829	352	504
290	.94172	3149	3.7749	1275	6.6203	22575	9.477	326	522
300	.91023	2946	3.6474	1190	6.39455	21063	9.151	304	540
310	.88077	2760	3.5284	1115	6.18392	19697	8.847	284	558
320	.85317	2592	3.4169	1046	5.98695	18456	8.563	266	576
330	.82725	2438	3.3123	983	5.80239	17343	8.297	250	594
340	.80287	2299	3.2140	926	5.62896	16318	8.047	235	612
350	.77988	2170	3.12143	8738	5.46578	15385	7.812	221	630
360	.75818	2053	3.03405	8256	5.31193	14532	7.591	209	648
370	.73765	1945	2.95149	7816	5.16661	13747	7.382	197	666
380	.71820	1844	2.87333	7412	5.02914	13028	7.185	187	684
390	.69976	1751	2.79921	7036	4.89886	12367	6.998	177	702
400	.68225	1666	2.72885	6688	4.77519	11749	6.8212	1684	720
410	.66559	1587	2.66197	6369	4.65770	11176	6.6528	1603	738
420	.64972	1513	2.59828	6068	4.54594	10652	6.4925	1525	756
430	.63459	1443	2.53760	5790	4.43942	10159	6.3400	1456	774
440	.62016	1380	2.47970	5530	4.33783	9699	6.1944	1388	792
450	.60636		2.42440		4.24084		6.0556		810

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure 1 atm		4 atm		7 atm		10 atm		T °R
450	.60636	-1319	2.42440	-5289	4.24084	-9273	6.0556	-1328	810
460	.59317	1263	2.37151	5060	4.14811	8874	5.9228	1269	828
470	.58054	1210	2.32091	4848	4.05937	8497	5.7959	1216	846
480	.56844	1161	2.27243	4651	3.97440	8150	5.6743	1166	864
490	.55683	1115	2.22592	4463	3.89290	7816	5.5577	1118	882
500	.54568	1070	2.18129	4286	3.81474	7510	5.4459	1074	900
510	.53498	1030	2.13843	4121	3.73964	7217	5.3385	1031	918
520	.52468	990	2.09722	3963	3.66747	6941	5.2354	993	936
530	.51478	953	2.05759	3818	3.59806	6685	5.1361	955	954
540	.50525	920	2.01941	3678	3.53121	6437	5.0406	920	972
550	.49605	886	1.98263	3544	3.46684	6205	4.9486	887	990
560	.48719	855	1.94719	3420	3.40479	5986	4.8599	855	1008
570	.47864	825	1.91299	3302	3.34493	5781	4.7744	826	1026
580	.47039	798	1.87997	3190	3.28712	5581	4.6918	797	1044
590	.46241	771	1.84807	3084	3.23131	5395	4.6121	770	1062
600	.45470	745	1.81723	2981	3.17736	5215	4.5351	746	1080
610	.44725	722	1.78742	2886	3.12521	5047	4.4605	720	1098
620	.44003	698	1.75856	2793	3.07474	4886	4.3885	698	1116
630	.43305	677	1.73063	2706	3.02588	4734	4.3187	676	1134
640	.42628	656	1.70357	2623	2.97854	4588	4.2511	655	1152
650	.41972	636	1.67734	2541	2.93266	4447	4.1856	635	1170
660	.41336	617	1.65193	2467	2.88819	4313	4.1221	615	1188
670	.40719	599	1.62726	2393	2.84506	4187	4.0606	598	1206
680	.40120	581	1.60333	2325	2.80319	4062	4.0008	580	1224
690	.39539	565	1.58008	2258	2.76257	3950	3.9428	564	1242
700	.38974	549	1.55750	2193	2.72307	3835	3.8864	548	1260
710	.38425	534	1.53557	2135	2.68472	3731	3.8316	532	1278
720	.37891	519	1.51422	2074	2.64741	3627	3.7784	517	1296
730	.37372	505	1.49348	2018	2.61114	3529	3.7267	504	1314
740	.36867	491	1.47330	1965	2.57585	3434	3.6763	490	1332
750	.36376	479	1.45365	1912	2.54151	3344	3.6273	477	1350
760	.35897	466	1.43453	1863	2.50807	3257	3.5796	465	1368
770	.35431	455	1.41590	1815	2.47550	3172	3.5331	453	1386
780	.34976	442	1.39775	1770	2.44378	3093	3.4878	441	1404
790	.34534	432	1.38005	1723	2.41285	3016	3.4437	431	1422
800	.34102		1.36282		2.38269		3.4006		1440

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
800	.34102	-2006	1.36282	-8016	2.38269	-14009	3.4006	-1999	1440
850	.32096	1783	1.28266	7123	2.24260	12451	3.2007	1776	1530
900	.30313	1595	1.21143	6373	2.11809	11139	3.0231	1590	1620
950	.28718	1436	1.14770	5735	2.00670	10024	2.8641	1430	1710
1000	.27282	1299	1.09035	5189	1.90646	9070	2.7211	1294	1800
1050	.25983	1181	1.03846	4717	1.81576	8245	2.5917	1176	1890
1100	.24802	1078	.99129	4308	1.73331	7527	2.4741	1074	1980
1150	.23724	988	.94821	3949	1.65804	6901	2.3667	9842	2070
1200	.22736	909	.90872	3632	1.58903	6348	2.26828	9058	2160
1250	.21827	840	.87240	3353	1.52555	5861	2.17770	8361	2250
1300	.20987	777	.83887	3105	1.46694	5426	2.09409	7742	2340
1350	.20210	722	.80782	2883	1.41268	5040	2.01667	7191	2430
1400	.19488	672	.77899	2684	1.36228	4692	1.94476	6695	2520
1450	.18816	627	.75215	2505	1.31536	4379	1.87781	6248	2610
1500	.18189	586	.72710	2344	1.27157	4097	1.81533	5847	2700
1550	.17603	550	.70366	2198	1.23060	3841	1.75686	5480	2790
1600	.17053	517	.68168	2064	1.19219	3608	1.70206	5150	2880
1650	.16536	486	.66104	1943	1.15611	3397	1.65056	4846	2970
1700	.16050	459	.64161	1832	1.12214	3202	1.60210	4570	3060
1750	.15591	433	.62329	1730	1.09012	3025	1.55640	4316	3150
1800	.15158	409	.60599	1637	1.05987	2861	1.51324	4084	3240
1850	.14749	388	.58962	1550	1.03126	2711	1.47240	3867	3330
1900	.14361	369	.57412	1472	1.00415	2572	1.43373	3671	3420
1950	.13992	349	.55940	1397	.97843	2443	1.39702	3487	3510
2000	.13643	333	.54543	1330	.95400	2325	1.36215	3319	3600
2050	.13310	317	.53213	1266	.93075	2213	1.32896	3159	3690
2100	.12993	302	.51947	1208	.90862	2112	1.29737	3012	3780
2150	.12691	288	.50739	1152	.88750	2014	1.26725	2876	3870
2200	.12403	276	.49587	1101	.86736	1926	1.23849	2749	3960
2250	.12127	264	.48486	1054	.84810	1842	1.21100	2627	4050
2300	.11863		.47432		.82968		1.18473		4140

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure 1 atm		4 atm		7 atm		10 atm		T °R
2300	.11863	-252	.47432	-1009	.82968	-1763	1.18473	-2518	4140
2350	.11611	242	.46423	966	.81205	1690	1.15955	2412	4230
2400	.11369	232	.45457	927	.79515	1621	1.13543	2314	4320
2450	.11137	222	.44530	890	.77894	1557	1.11229	2222	4410
2500	.10915	215	.43640	856	.76337	1496	1.09007	2135	4500
2550	.01700	205	.42784	822	.74841	1437	1.06872	2052	4590
2600	.10495	198	.41962	791	.73404	1384	1.04820	1975	4680
2650	.10297	191	.41171	762	.72020	1332	1.02845	1902	4770
2700	.10106	184	.40409	735	.70688	1285	1.00943	1833	4860
2750	.09922	177	.39674	708	.69403	1238	.99110	1768	4950
2800	.09745	171	.38966	683	.68165	1195	.97342	1706	5040
2850	.09574	165	.38283	660	.66970	1153	.95636	1647	5130
2900	.09409	159	.37623	637	.65817	1115	.93989	1590	5220
2950	.09250	154	.36986	616	.64702	1077	.92399	1538	5310
3000	.09096		.36370		.63625		.90861		5400

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
150	19.70	-152							270
160	18.18	126	98.0	-141					288
170	16.92	108	83.9	92	214.0	490			306
180	15.84	94	74.7	69	165.0	-256	335.	-94	324
190	14.90	827	67.8	54	139.4	164	241.	42	342
200	14.073	734	62.4	43	123.0	117	198.6	257	360
210	13.339	656	58.1	37	111.3	90	172.9	175	378
220	12.683	592	54.4	31	102.3	73	155.4	131	396
230	12.091	536	51.3	274	95.0	60	142.3	104	414
240	11.555	488	48.56	242	89.0	511	131.9	849	432
250	11.067	447	46.14	216	83.89	446	123.41	722	450
260	10.620	412	43.98	193	79.43	3905	116.19	622	468
270	10.208	379	42.05	176	75.525	3490	109.97	547	486
280	9.829	352	40.29	160	72.035	3124	104.50	483	504
290	9.477	326	38.69	1459	68.911	2829	99.67	433	522
300	9.151	304	37.231	1347	66.082	2567	95.34	391	540
310	8.847	284	35.884	1245	63.515	2357	91.43	356	558
320	8.563	266	34.639	1154	61.158	2161	87.87	3252	576
330	8.297	250	33.485	1075	58.997	2003	84.618	2999	594
340	8.047	235	32.410	1002	56.994	1852	81.619	2757	612
350	7.812	221	31.408	938	55.142	1726	78.862	2553	630
360	7.591	209	30.470	880	53.416	1605	76.309	2375	648
370	7.382	197	29.590	828	51.811	1510	73.934	2219	666
380	7.185	187	28.762	780	50.301	1412	71.715	2082	684
390	6.998	177	27.982	736	48.889	1332	69.633	1943	702
400	6.8212	1684	27.246	696	47.557	1252	67.690	1827	720
410	6.6528	1603	26.550	661	46.305	1183	65.863	1721	738
420	6.4925	1525	25.889	626	45.122	1124	64.142	1634	756
430	6.3400	1456	25.263	596	43.998	1059	62.508	1534	774
440	6.1944	1388	24.667	567	42.939	1008	60.974	1461	792
450	6.0556		24.100		41.931		59.513		810

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
450	6.0556	-1328	24.100	-540	41.931	-960	59.513	-1379	810
460	5.9228	1269	23.560	516	40.971	915	58.134	1326	828
470	5.7959	1216	23.044	493	40.056	870	56.808	1249	846
480	5.6743	1166	22.551	471	39.186	833	55.559	1192	864
490	5.5577	1118	22.080	452	38.353	797	54.367	1150	882
500	5.4459	1074	21.628	433	37.556	758	53.217	1089	900
510	5.3385	1031	21.195	415	36.798	733	52.128	1042	918
520	5.2354	993	20.780	399	36.065	697	51.086	998	936
530	5.1361	955	20.381	383	35.368	672	50.088	966	954
540	5.0406	920	19.998	3686	34.696	645	49.122	917	972
550	4.9486	887	19.6294	3551	34.051	624	48.205	888	990
560	4.8599	855	19.2743	3421	33.427	596	47.317	848	1008
570	4.7744	826	18.9322	3299	32.831	576	46.469	823	1026
580	4.6918	797	18.6023	3182	32.255	553	45.646	787	1044
590	4.6121	770	18.2841	3074	31.702	537	44.859	761	1062
600	4.5351	746	17.9767	2969	31.165	517	44.098	739	1080
610	4.4605	720	17.6798	2873	30.648	500	43.359	716	1098
620	4.3885	698	17.3925	2777	30.148	485	42.643	685	1116
630	4.3187	676	17.1148	2688	29.663	469	41.958	656	1134
640	4.2511	655	16.8460	2601	29.194	449	41.302	635	1152
650	4.1856	635	16.5859	2523	28.745	438	40.667	620	1170
660	4.1221	615	16.3336	2447	28.307	426	40.047	606	1188
670	4.0606	598	16.0889	2373	27.881	410	39.441	584	1206
680	4.0008	580	15.8516	2302	27.471	400	38.857	563	1224
690	3.9428	564	15.6214	2234	27.071	387	38.294	547	1242
700	3.8864	548	15.3980	2171	26.684	376	37.747	531	1260
710	3.8316	532	15.1809	2109	26.308	365	37.216	517	1278
720	3.7784	517	14.9700	2053	25.943	356	36.699	503	1296
730	3.7267	504	14.7647	1995	25.587	346	36.196	489	1314
740	3.6763	490	14.5652	1940	25.241	334	35.707	473	1332
750	3.6273	477	14.3712	1890	24.907	327	35.234	463	1350
760	3.5796	465	14.1822	1838	24.580	317	34.771	445	1368
770	3.5331	453	13.9984	1790	24.263	311	34.326	440	1386
780	3.4878	441	13.8194	1748	23.952	303	33.886	429	1404
790	3.4437	431	13.6446	1700	23.649	294	33.457	412	1422
800	3.4006		13.4746		23.355		33.045		1440

Table 9.18 Density of Oxygen

ρ/ρ_0

T °K	10 atm		40 atm		70 atm		100 atm		T °R
800	3.4006	-1999	13.4746	-7904	23.355	-1367	33.045	-1929	1440
850	3.2007	1776	12.6842	7019	21.988	1212	31.116	1712	1530
900	3.0231	1590	11.9823	6276	20.776	1084	29.404	1526	1620
950	2.8641	1430	11.3547	5646	19.692	975	27.878	1373	1710
1000	2.7211	1294	10.7901	5108	18.717	881	26.505	1242	1800
1050	2.5917	1176	10.2793	4643	17.836	802	25.263	1132	1890
1100	2.4741	1074	9.8150	4239	17.034	733	24.131	1032	1980
1150	2.3667	9842	9.3911	3887	16.301	670	23.099	945	2070
1200	2.26828	9058	9.0024	3576	15.631	619	22.154	872	2160
1250	2.17770	8361	8.6448	3303	15.012	569	21.282	802	2250
1300	2.09409	7742	8.3145	3058	14.443	528	20.480	745	2340
1350	2.01667	7191	8.0087	2840	13.915	492	19.735	694	2430
1400	1.94476	6695	7.7247	2646	13.423	458	19.041	646	2520
1450	1.87781	6248	7.4601	2470	12.965	426	18.395	601	2610
1500	1.81533	5847	7.2131	2311	12.539	399	17.794	565	2700
1550	1.75686	5480	6.9820	2167	12.140	376	17.229	529	2790
1600	1.70206	5150	6.7653	2036	11.764	352	16.700	496	2880
1650	1.65056	4846	6.5617	1917	11.412	332	16.204	469	2970
1700	1.60210	4570	6.3700	1808	11.080	313	15.735	442	3060
1750	1.55640	4316	6.1892	1708	10.767	295	15.293	419	3150
1800	1.51324	4084	6.0184	1616	10.472	280	14.874	395	3240
1850	1.47240	3867	5.8568	1531	10.192	265	14.479	374	3330
1900	1.43373	3671	5.7037	1453	9.927	252	14.105	357	3420
1950	1.39702	3487	5.5584	1382	9.675	239	13.748	338	3510
2000	1.36215	3319	5.4202	1314	9.436	228	13.410	322	3600
2050	1.32896	3159	5.2888	1251	9.208	217	13.088	307	3690
2100	1.29737	3012	5.1637	1194	8.991	206	12.781	293	3780
2150	1.26725	2876	5.0443	1140	8.785	198	12.488	280	3870
2200	1.23849	2749	4.9303	1089	8.587	190	12.208	267	3960
2250	1.21100	2627	4.8214	1041	8.397	180	11.941	255	4050
2300	1.18473		4.7173		8.217		11.686		4140

Table 9.18 Density of Oxygen ρ/ρ_0

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
2300	1.18473	-2518	4.7173	-998	8.217	-173	11.686	-245	4140
2350	1.15955	2412	4.6175	957	8.044	166	11.441	235	4230
2400	1.13543	2314	4.5218	918	7.878	159	11.206	226	4320
2450	1.11229	2222	4.4300	881	7.719	153	10.980	217	4410
2500	1.09007	2135	4.3419	847	7.566	147	10.763	208	4500
2550	1.06872	2052	4.2572	814	7.419	141	10.555	200	4590
2600	1.04820	1975	4.1758	784	7.278	136	10.355	194	4680
2650	1.02845	1902	4.0974	755	7.142	132	10.161	185	4770
2700	1.00943	1833	4.0219	728	7.010	126	9.976	179	4860
2750	.99110	1768	3.9491	701	6.884	122	9.797	173	4950
2800	.97342	1706	3.8790	678	6.762	117	9.624	167	5040
2850	.95636	1647	3.8112	654	6.645	114	9.457	161	5130
2900	.93989	1590	3.7458	631	6.531	110	9.296	155	5220
2950	.92399	1538	3.6827	611	6.421	106	9.141	151	5310
3000	.90861		3.6216		6.315		8.990		5400

Table 9.18 Density of Molecular Oxygen

The Property Tabulated

The density relative to standard conditions, ρ/ρ_0, of molecular oxygen is tabulated as a function of temperature in degrees Kelvin and Rankine and as a function of pressure in standard atmospheres. Standard conditions are one atmosphere of pressure and 0°C(273.16°K). The densities tabulated herein were computed from the equation

$$\rho/\rho_0 = \frac{T_0 Z_0 P}{P_0 T Z}$$

where P is the pressure in atmospheres, T is the Kelvin temperature, Z is the compressibility factor given in Table 9.20 of this series and $T_0 Z_0/P_0 = 272.901°K\ atm^{-1}$.

Reliability of the Table

The values presented in this table are derived from the values of compressibility in Table 9.20 and have identical errors when expressed relative to the values tabulated. On the basis of the estimated errors for that table, this table has entries that may be in error by 6 in the next to the last place but many entries are more precise. At low pressures and high temperatures, the values are subject to considerable change due to dissociation.

Interpolation

The error produced by linear interpolation does not in general exceed one eighth of the second difference. If greater accuracy is desired four or five point Lagrangian interpolation may be used. An alternative method is to interpolate in the table of compressibility to obtain Z at the desired temperature and pressure and then to calculate ρ/ρ_0 by the above formula.

Conversion Factors

The function in this table has been expressed in dimensionless form. In order that it may be converted readily to any system of units, values of ρ_0 are listed for frequently used units. For conversion factors not listed here see Table 1.30 of this series.

To convert tabulated value of	To	Having the dimensions indicated below	Multiply by
ρ/ρ_0	ρ	g cm^{-3}	1.42900×10^{-3}
		mole cm^{-3}	4.46564×10^{-5}
		g liter^{-1}	1.42904
		lb in^{-3}	5.16262×10^{-5}
		lb ft^{-3}	.0892101

U. S. Department of Commerce National Bureau of Standards

The NBS-NACA Tables of Thermal Properties of Gases

Table 9.20 Compressibility Factor for Molecular Oxygen
$Z=PV/RT$

by

Harold W. Woolley

Reissue
1953

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure: .01 atm	Δ	.1 atm	Δ	.4 atm	Δ	.7 atm	Δ	1 atm	Δ	T °R
100	.99978	5	.99781	50	.99114	206	.98431	371	.97724	553	180
110	.99983	4	.99831	36	.99320	146	.98802	259	.98277	375	198
120	.99987	2	.99867	26	.99466	107	.99061	188	.98652	272	216
130	.99989	2	.99893	20	.99573	80	.99249	142	.98924	204	234
140	.99991	2	.99913	16	.99653	62	.99391	109	.99128	156	252
150	.99993		.99929	12	.99715	49	.99500	86	.99284	123	270
160	.99994		.99941	10	.99764	39	.99586	68	.99407	98	288
170	.99995		.99951	8	.99803	31	.99654	55	.99505	78	306
180	.99996		.99959	6	.99834	25	.99709	45	.99583	65	324
190	.99996		.99965	5	.99859	21	.99754	37	.99648	53	342
200	.99997		.99970	5	.99880	18	.99791	31	.99701	44	360
210	.99997		.99975	3	.99898	15	.99822	26	.99745	37	378
220	.99998		.99978	3	.99913	13	.99848	22	.99782	32	396
230	.99998		.99981	3	.99926	10	.99870	18	.99814	27	414
240	.99998		.99984	2	.99936	9	.99888	16	.99841	23	432
250	.99999		.99986		.99945	8	.99904	14	.99864	19	450
260	.99999		.99988		.99953	7	.99918	12	.99883	17	468
270	.99999		.99990		.99960	6	.99930	11	.99900	15	486
280	.99999		.99992		.99966	5	.99941	9	.99915	13	504
290	.99999		.99993		.99971	5	.99950	8	.99928	11	522
300	.99999		.99994		.99976	4	.99958	7	.99939	10	540
310	.99999		.99995		.99980	3	.99965	6	.99949	9	558
320	1.00000		.99996		.99983	3	.99971	5	.99958	8	576
330	1.00000		.99997		.99986	3	.99976	5	.99966	7	594
340	1.00000		.99997		.99989	3	.99981	4	.99973	6	612
350	1.00000		.99998		.99992		.99985		.99979	5	630
360	1.00000		.99998		.99994		.99989		.99984	5	648
370	1.00000		.99999		.99996		.99993		.99989	5	666
380	1.00000		.99999		.99998		.99996		.99994	4	684
390	1.00000		1.00000		.99999		.99998		.99998	3	702
400	1.00000		1.00000		1.00000		1.00001		1.00001		720
410	1.00000		1.00000		1.00002		1.00003		1.00004		738
420	1.00000		1.00001		1.00003		1.00005		1.00007		756
430	1.00000		1.00001		1.00004		1.00007		1.00010		774
440	1.00000		1.00001		1.00005		1.00008		1.00012		792
450	1.00000		1.00002		1.00006		1.00010		1.00014		810

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure .01 atm	.1 atm	.4 atm	.17 atm	1 atm	T °R
450	1.00000	1.00002	1.00006	1.00010	1.00014	810
460	1.00000	1.00002	1.00006	1.00011	1.00016	828
470	1.00000	1.00002	1.00007	1.00012	1.00018	846
480	1.00000	1.00002	1.00008	1.00013	1.00019	864
490	1.00000	1.00002	1.00008	1.00014	1.00020	882
500	1.00000	1.00002	1.00009	1.00015	1.00022	900
510	1.00000	1.00002	1.00009	1.00016	1.00023	918
520	1.00000	1.00002	1.00010	1.00017	1.00024	936
530	1.00000	1.00002	1.00010	1.00017	1.00025	954
540	1.00000	1.00003	1.00010	1.00018	1.00025	972
550	1.00000	1.00003	1.00010	1.00018	1.00026	990
560	1.00000	1.00003	1.00010	1.00019	1.00027	1008
570	1.00000	1.00003	1.00011	1.00019	1.00027	1026
580	1.00000	1.00003	1.00011	1.00020	1.00028	1044
590	1.00000	1.00003	1.00011	1.00020	1.00028	1062
600	1.00000	1.00003	1.00012	1.00020	1.00029	1080
610	1.00000	1.00003	1.00012	1.00020	1.00029	1098
620	1.00000	1.00003	1.00012	1.00021	1.00030	1116
630	1.00000	1.00003	1.00012	1.00021	1.00030	1134
640	1.00000	1.00003	1.00012	1.00021	1.00030	1152
650	1.00000	1.00003	1.00012	1.00021	1.00030	1170
660	1.00000	1.00003	1.00012	1.00021	1.00030	1188
670	1.00000	1.00003	1.00012	1.00021	1.00031	1206
680	1.00000	1.00003	1.00012	1.00021	1.00031	1224
690	1.00000	1.00003	1.00012	1.00022	1.00031	1242
700	1.00000	1.00003	1.00012	1.00022	1.00031	1260
710	1.00000	1.00003	1.00012	1.00022	1.00031	1278
720	1.00000	1.00003	1.00012	1.00022	1.00031	1296
730	1.00000	1.00003	1.00012	1.00022	1.00031	1314
740	1.00000	1.00003	1.00012	1.00022	1.00031	1332
750	1.00000	1.00003	1.00012	1.00022	1.00031	1350
760	1.00000	1.00003	1.00012	1.00022	1.00031	1368
770	1.00000	1.00003	1.00012	1.00022	1.00031	1386
780	1.00000	1.00003	1.00012	1.00022	1.00031	1404
790	1.00000	1.00003	1.00012	1.00022	1.00031	1422
800	1.00000	1.00003	1.00012	1.00022	1.00031	1440

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure .01 atm	.1 atm	.4 atm	.7 atm	1 atm	T °R
800	1.00000	1.00003	1.00012	1.00022	1.00031	1440
850	1.00000	1.00003	1.00012	1.00021	1.00031	1530
900	1.00000	1.00003	1.00012	1.00021	1.00030	1620
950	1.00000	1.00003	1.00012	1.00021	1.00029	1710
1000	1.00000	1.00003	1.00012	1.00020	1.00029	1800
1050	1.00000	1.00003	1.00011	1.00020	1.00028	1890
1100	1.00000	1.00003	1.00011	1.00019	1.00027	1980
1150	1.00000	1.00003	1.00011	1.00019	1.00027	2070
1200	1.00000	1.00003	1.00010	1.00018	1.00026	2160
1250	1.00000	1.00003	1.00010	1.00018	1.00025	2250
1300	1.00000	1.00002	1.00010	1.00017	1.00025	2340
1350	1.00000	1.00002	1.00010	1.00017	1.00024	2430
1400	1.00000	1.00002	1.00009	1.00016	1.00023	2520
1450	1.00000	1.00002	1.00009	1.00016	1.00023	2610
1500	1.00000	1.00002	1.00009	1.00015	1.00022	2700
1550	1.00000	1.00002	1.00009	1.00015	1.00022	2790
1600	1.00000	1.00002	1.00008	1.00015	1.00021	2880
1650	1.00000	1.00002	1.00008	1.00014	1.00020	2970
1700	1.00000	1.00002	1.00008	1.00014	1.00020	3060
1750	1.00000	1.00002	1.00008	1.00014	1.00020	3150
1800	1.00000	1.00002	1.00008	1.00013	1.00019	3240
1850	1.00000	1.00002	1.00007	1.00013	1.00019	3330
1900	1.00000	1.00002	1.00007	1.00013	1.00018	3420
1950	1.00000	1.00002	1.00007	1.00012	1.00018	3510
2000	1.00000	1.00002	1.00007	1.00012	1.00017	3600
2050	1.00000	1.00002	1.00007	1.00012	1.00017	3690
2100	1.00000	1.00002	1.00007	1.00012	1.00017	3780
2150	1.00000	1.00002	1.00006	1.00011	1.00016	3870
2200	1.00000	1.00002	1.00006	1.00011	1.00016	3960
2250	1.00000	1.00002	1.00006	1.00011	1.00016	4050
2300	1.00000	1.00002	1.00006	1.00011	1.00015	4140

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure .01 atm	.1 atm	.4 atm	.7 atm	1 atm	T °R
2300	1.00000	1.00002	1.00006	1.00011	1.00015	4140
2350	1.00000	1.00001	1.00006	1.00010	1.00015	4230
2400	1.00000	1.00001	1.00006	1.00010	1.00015	4320
2450	1.00000	1.00001	1.00006	1.00010	1.00014	4410
2500	1.00000	1.00001	1.00006	1.00010	1.00014	4500
2550	1.00000	1.00001	1.00005	1.00010	1.00014	4590
2600	1.00000	1.00001	1.00005	1.00009	1.00014	4680
2650	1.00000	1.00001	1.00005	1.00009	1.00013	4770
2700	1.00000	1.00001	1.00005	1.00009	1.00013	4860
2750	1.00000	1.00001	1.00005	1.00009	1.00013	4950
2800	1.00000	1.00001	1.00005	1.00009	1.00013	5040
2850	1.00000	1.00001	1.00005	1.00009	1.00012	5130
2900	1.00000	1.00001	1.00005	1.00009	1.00012	5220
2950	1.00000	1.00001	1.00005	1.00008	1.00012	5310
3000	1.00000	1.00001	1.00005	1.00008	1.00012	5400

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	1 atm		4 atm		7 atm		10 atm		T °R
100	.97724	553							180
110	.98277	375	.9227	200					198
120	.98652	272	.9427	126	.891	27			216
130	.98924	204	.9553	89	.9179	174	.876	28	234
140	.99128	156	.9642	66	.9353	124	.9043	193	252
150	.99284	123	.9[illegible]08	51	.9477	94	.9236	141	270
160	.99407	98	.9759	40	.9571	73	.9377	109	288
170	.99505	78	.9799	33	.9644	58	.9486	85	306
180	.99583	65	.9832	26	.9702	47	.9571	69	324
190	.99648	53	.9858	21	.9749	39	.9640	56	342
200	.99701	44	.98796	180	.97880	319	.96956	461	360
210	.99745	37	.98976	150	.98199	266	.97417	384	378
220	.99782	32	.99126	127	.98465	225	.97801	324	396
230	.99814	27	.99253	108	.98690	190	.98125	274	414
240	.99841	23	.99361	92	.98880	163	.98399	234	432
250	.99864	19	.99453	80	.99043	140	.98633	200	450
260	.99883	17	.99533	69	.99183	121	.98833	173	468
270	.99900	15	.99602	59	.99304	104	.99006	151	486
280	.99915	13	.99661	52	.99408	92	.99157	131	504
290	.99928	11	.99713	46	.99500	80	.99288	114	522
300	.99939	10	.99759	40	.99580	70	.99402	100	540
310	.99949	9	.99799	35	.99650	62	.99502	88	558
320	.99958	8	.99834	31	.99712	54	.99590	78	576
330	.99966	7	.99865	28	.99766	49	.99668	70	594
340	.99973	6	.99893	25	.99815	43	.99738	61	612
350	.99979	5	.99918	22	.99858	38	.99799	54	630
360	.99984	5	.99940	19	.99896	34	.99853	49	648
370	.99989	5	.99959	17	.99930	30	.99902	43	666
380	.99994	4	.99976	16	.99960	27	.99945	39	684
390	.99998	3	.99992	14	.99987	25	.99984	35	702
400	1.00001	3	1.00006	12	1.00012	22	1.00019	31	720
410	1.00004	3	1.00018	12	1.00034	19	1.00050	28	738
420	1.00007	3	1.00030	10	1.00053	18	1.00078	25	756
430	1.00010	2	1.00040	9	1.00071	16	1.00103	23	774
440	1.00012	2	1.00049	8	1.00087	14	1.00126	20	792
450	1.00014		1.00057		1.00101		1.00146		810

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure 1 atm	4 atm		7 atm		10 atm		T °R
450	1.00014	1.00057		1.00101		1.00146		810
460	1.00016	1.00065	8	1.00114	13	1.00165	19	828
470	1.00018	1.00071	6	1.00126	12	1.00181	16	846
480	1.00019	1.00077	6	1.00136	10	1.00196	15	864
490	1.00020	1.00083	6	1.00146	10	1.00210	14	882
500	1.00022	1.00088	5	1.00154	8	1.00222	12	900
510	1.00023	1.00092		1.00162	8	1.00233	11	918
520	1.00024	1.00096		1.00169	7	1.00242	9	936
530	1.00025	1.00099		1.00175	6	1.00251	9	954
540	1.00025	1.00103		1.00181	6	1.00259	8	972
550	1.00026	1.00106		1.00186	5	1.00266	7	990
560	1.00027	1.00108		1.00190		1.00273	7	1008
570	1.00027	1.00110		1.00194		1.00279	6	1026
580	1.00028	1.00112		1.00198		1.00284	5	1044
590	1.00028	1.00114		1.00201		1.00288	4	1062
600	1.00029	1.00116		1.00204		1.00292	4	1080
610	1.00029	1.00117		1.00206		1.00296		1098
620	1.00030	1.00119		1.00208		1.00299		1116
630	1.00030	1.00120		1.00210		1.00302		1134
640	1.00030	1.00121		1.00212		1.00304		1152
650	1.00030	1.00122		1.00214		1.00306		1170
660	1.00030	1.00122		1.00215		1.00308		1188
670	1.00031	1.00123		1.00216		1.00309		1206
680	1.00031	1.00123		1.00217		1.00310		1224
690	1.00031	1.00124		1.00217		1.00311		1242
700	1.00031	1.00124		1.00218		1.00312		1260
710	1.00031	1.00124		1.00218		1.00313		1278
720	1.00031	1.00125		1.00219		1.00313		1296
730	1.00031	1.00125		1.00219		1.00313		1314
740	1.00031	1.00125		1.00219		1.00313		1332
750	1.00031	1.00125		1.00219		1.00313		1350
760	1.00031	1.00125		1.00219		1.00313		1368
770	1.00031	1.00125		1.00219		1.00313		1386
780	1.00031	1.00125		1.00218		1.00313		1404
790	1.00031	1.00125		1.00218		1.00312		1422
800	1.00031	1.00124		1.00218		1.00311		1440

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure 1 atm	4 atm	7 atm	10 atm	T °R
800	1.00031	1.00124	1.00218	1.00311	1440
850	1.00031	1.00123	1.00215	1.00307	1530
900	1.00030	1.00121	1.00211	1.00302	1620
950	1.00029	1.00118	1.00207	1.00295	1710
1000	1.00029	1.00115	1.00202	1.00288	1800
1050	1.00028	1.00112	1.00197	1.00281	1890
1100	1.00027	1.00109	1.00192	1.00274	1980
1150	1.00027	1.00107	1.00187	1.00267	2070
1200	1.00026	1.00104	1.00182	1.00260	2160
1250	1.00025	1.00101	1.00177	1.00253	2250
1300	1.00025	1.00098	1.00172	1.00246	2340
1350	1.00024	1.00096	1.00167	1.00239	2430
1400	1.00023	1.00093	1.00163	1.00233	2520
1450	1.00023	1.00091	1.00159	1.00227	2610
1500	1.00022	1.00088	1.00155	1.00221	2700
1550	1.00022	1.00086	1.00151	1.00216	2790
1600	1.00021	1.00084	1.00147	1.00210	2880
1650	1.00020	1.00082	1.00143	1.00205	2970
1700	1.00020	1.00080	1.00140	1.00200	3060
1750	1.00020	1.00078	1.00136	1.00195	3150
1800	1.00019	1.00076	1.00133	1.00190	3240
1850	1.00019	1.00074	1.00130	1.00186	3330
1900	1.00018	1.00072	1.00127	1.00181	3420
1950	1.00018	1.00071	1.00124	1.00177	3510
2000	1.00017	1.00069	1.00121	1.00173	3600
2050	1.00017	1.00068	1.00119	1.00170	3690
2100	1.00017	1.00066	1.00116	1.00166	3780
2150	1.00016	1.00065	1.00114	1.00162	3870
2200	1.00016	1.00063	1.00111	1.00159	3960
2250	1.00016	1.00062	1.00109	1.00156	4050
2300	1.00015	1.00061	1.00107	1.00152	4140

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	1 atm	4 atm	7 atm	10 atm	T °R
2300	1.00015	1.00061	1.00107	1.00152	4140
2350	1.00015	1.00060	1.00104	1.00149	4230
2400	1.00015	1.00058	1.00102	1.00146	4320
2450	1.00014	1.00057	1.00100	1.00143	4410
2500	1.00014	1.00056	1.00098	1.00141	4500
2550	1.00014	1.00055	1.00097	1.00138	4590
2600	1.00014	1.00054	1.00095	1.00135	4680
2650	1.00013	1.00053	1.00093	1.00133	4770
2700	1.00013	1.00052	1.00091	1.00130	4860
2750	1.00013	1.00051	1.00090	1.00128	4950
2800	1.00013	1.00050	1.00088	1.00126	5040
2850	1.00012	1.00049	1.00087	1.00124	5130
2900	1.00012	1.00049	1.00085	1.00122	5220
2950	1.00012	1.00048	1.00084	1.00119	5310
3000	1.00012	1.00047	1.00082	1.00117	5400

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
100									180
110									198
120									216
130									234
140									252
150	.9236	141							270
160	.9377	109	.696	69					288
170	.9486	85	.765	47	.525	118			306
180	.9571	69	.812	35	.643	78	.452	143	324
190	.9640	56	.847	26	.721	55	.595	92	342
200	.96956	461	.8734	209	.7764	408	.6871	641	360
210	.97417	384	.8943	169	.8172	315	.7512	468	378
220	.97801	324	.9112	138	.8487	250	.7980	357	396
230	.98125	274	.9250	115	.8737	203	.8337	280	414
240	.98399	234	.9365	97	.8940	168	.8617	228	432
250	.98633	200	.9462	822	.9108	141	.8845	188	450
260	.98833	173	.95442	703	.9249	119	.9033	158	468
270	.99006	151	.96145	606	.9368	103	.9191	135	486
280	.99157	131	.96751	524	.9471	88	.9326	115	504
290	.99288	114	.97275	456	.9559	77	.9441	100	522
300	.99402	100	.97731	398	.9636	66	.9541	87	540
310	.99502	88	.98129	350	.9702	59	.9628	77	558
320	.99590	78	.98479	308	.9761	51	.9705	68	576
330	.99668	70	.98787	272	.9812	46	.9773	61	594
340	.99738	61	.99059	241	.9858	40	.9834	53	612
350	.99799	54	.99300	213	.9898	36	.9887	47	630
360	.99853	49	.99513	189	.9934	31	.9934	42	648
370	.99902	43	.99702	171	.9965	29	.9976	38	666
380	.99945	39	.99873	153	.9994	25	1.0014	35	684
390	.99984	35	1.00026	135	1.0019	23	1.0049	30	702
400	1.00019	31	1.00161	119	1.0042	20	1.0079	27	720
410	1.00050	28	1.00280	109	1.0062	18	1.0106	24	738
420	1.00078	25	1.00389	98	1.0080	17	1.0130	23	756
430	1.00103	23	1.00487	87	1.0097	14	1.0153	19	774
440	1.00126	20	1.00574	78	1.0111	13	1.0172	18	792
450	1.00146		1.00652		1.0124		1.0190		810

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

	Pressure								
T °K	10 atm		40 atm		70 atm		100 atm		T °R
450	1.00146	19	1.00652	71	1.0124	12	1.0190	15	810
460	1.00165	16	1.00723	63	1.0136	11	1.0205	16	828
470	1.00181	15	1.00786	57	1.0147	9	1.0221	12	846
480	1.00196	14	1.00843	51	1.0156	9	1.0233	11	864
490	1.00210	12	1.00894	48	1.0165	8	1.0244	12	882
500	1.00222	11	1.00942	41	1.0173	6	1.0256	9	900
510	1.00233	9	1.00983	36	1.0179	7	1.0265	8	918
520	1.00242	9	1.01019	33	1.0186	5	1.0273	7	936
530	1.00251	8	1.01052	31	1.0191	5	1.0280	8	954
540	1.00259	7	1.01083	27	1.0196	4	1.0288	5	972
550	1.00266	7	1.01110	24	1.0200	5	1.0293	6	990
560	1.00273	6	1.01134	21	1.0205	3	1.0299	4	1008
570	1.00279	5	1.01155	19	1.0208	3	1.0303	5	1026
580	1.00284	4	1.01174	16	1.0211	2	1.0308	3	1044
590	1.00288	4	1.01190	15	1.0213	3	1.0311	3	1062
600	1.00292		1.01205	13	1.0216		1.0314		1080
610	1.00296		1.01218	12	1.0218		1.0318		1098
620	1.00299		1.01230	10	1.0220		1.0322		1116
630	1.00302		1.01240	8	1.0222		1.0324		1134
640	1.00304		1.01248	6	1.0224		1.0324		1152
650	1.00306		1.01254	6	1.0224		1.0324		1170
660	1.00308		1.01260	6	1.0225		1.0325		1188
670	1.00309		1.01266	4	1.0226		1.0327		1206
680	1.00310		1.01270	3	1.0226		1.0328		1224
690	1.00311		1.01273	2	1.0227		1.0328		1242
700	1.00312		1.01275		1.0227		1.0328		1260
710	1.00313		1.01276		1.0227		1.0328		1278
720	1.00313		1.01277		1.0227		1.0328		1296
730	1.00313		1.01278		1.0227		1.0328		1314
740	1.00313		1.01278		10.227		1.0328		1332
750	1.00313		1.01277		1.0226		1.0327		1350
760	1.00313		1.01276		1.0226		1.0327		1368
770	1.00313		1.01273		1.0225		1.0325		1386
780	1.00313		1.01270		1.0225		1.0325		1404
790	1.00312		1.01269		1.0225		1.0325		1422
800	1.00311		1.01265		1.0224		1.0323		1440

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
800	1.00311	-4	1.01265	-18	1.0224	-3	1.0323	-5	1440
850	1.00307	-5	1.01247	-24	1.0221	-5	1.0318	-6	1530
900	1.00302	-7	1.01223	-27	1.0216	-5	1.0312	-8	1620
950	1.00295	-7	1.01196	-29	1.0211	-5	1.0304	-8	1710
1000	1.00288	-7	1.01167	-30	1.0206	-6	1.0296	-8	1800
1050	1.00281	-7	1.01137	-30	1.0200	-5	1.0288	-7	1890
1100	1.00274	-7	1.01107	-31	1.0195	-5	1.0281	-8	1980
1150	1.00267	-7	1.01076	-29	1.0190	-6	1.0273	-8	2070
1200	1.00260	-7	1.01047	-29	1.0184	-4	1.0265	-7	2160
1250	1.00253	-7	1.01018	-27	1.0180	-6	1.0258	-8	2250
1300	1.00246	-7	1.00991	-27	1.0174	-5	1.0250	-7	2340
1350	1.00239	-6	1.00964	-26	1.0169	-4	1.0243	-6	2430
1400	1.00233	-6	1.00938	-24	1.0165	-4	1.0237	-6	2520
1450	1.00227	-6	1.00914	-24	1.0161	-5	1.0231	-7	2610
1500	1.00221	-5	1.00890	-23	1.0156	-4	1.0224	-5	2700
1550	1.00216	-6	1.00867	-22	1.0152	-3	1.0219	-6	2790
1600	1.00210	-5	1.00845	-22	1.0149	-4	1.0213	-6	2880
1650	1.00205	-5	1.00823	-20	1.0145	-4	1.0207	-5	2970
1700	1.00200	-5	1.00803	-20	1.0141	-3	1.0202	-5	3060
1750	1.00195	-5	1.00783	-18	1.0138	-4	1.0197	-4	3150
1800	1.00190	-4	1.00765	-18	1.0134	-3	1.0193	-5	3240
1850	1.00186	-5	1.00747	-19	1.0131	-3	1.0188	-5	3330
1900	1.00181	-4	1.00728	-17	1.0128	-3	1.0183	-4	3420
1950	1.00177	-4	1.00711	-15	1.0125	-3	1.0179	-4	3510
2000	1.00173	-3	1.00696	-15	1.0122	-3	1.0175	-4	3600
2050	1.00170	-4	1.00681	-15	1.0119	-2	1.0171	-4	3690
2100	1.00166	-4	1.00666	-14	1.0117	-3	1.0167	-3	3780
2150	1.00162	-3	1.00652	-14	1.0114	-2	1.0164	-3	3870
2200	1.00159	-3	1.00638	-14	1.0112	-2	1.0161	-4	3960
2250	1.00156	-4	1.00624	-14	1.0110	-3	1.0157	-4	4050
2300	1.00152		1.00610		1.0107		1.0153		4140

Table 9.20 Compressibility Factor for Oxygen Z=PV/RT

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
2300	1.00152	-3	1.00610	-12	1.0107	-2	1.0153	-3	4140
2350	1.00149	-3	1.00598	-12	1.0105	-2	1.0150	-3	4230
2400	1.00146	-3	1.00586	-11	1.0103	-2	1.0147	-3	4320
2450	1.00143	-2	1.00575	-11	1.0101	-2	1.0144	-2	4410
2500	1.00141	-3	1.00564	-11	1.0099	-2	1.0142	-3	4500
2550	1.00138	-3	1.00553	-10	1.0097	-2	1.0139	-3	4590
2600	1.00135	-2	1.00543	-10	1.0095	-2	1.0136	-2	4680
2650	1.00133	-3	1.00533	-10	1.0093	-1	1.0134	-3	4770
2700	1.00130	-2	1.00523	- 9	1.0092	-2	1.0131	-2	4860
2750	1.00128	-2	1.00514	- 9	1.0090	-1	1.0129	-2	4950
2800	1.00126	-2	1.00505	- 9	1.0089	-2	1.0127	-2	5040
2850	1.00124	-2	1.00496	- 8	1.0087	-1	1.0125	-3	5130
2900	1.00122	-3	1.00488	- 9	1.0086	-2	1.0122	-2	5220
2950	1.00119	-2	1.00479	- 8	1.0084	-1	1.0120	-2	5310
3000	1.00117		1.00471		1.0083		1.0118		5400

Table 9.20 Compressibility Factor for Molecular Oxygen

The Property Tabulated

The dimensionless compressibility factor, $Z = PV/RT$, for molecular oxygen is tabulated in terms of temperature in degrees Kelvin and Rankine. The values are those which would exist if there were no dissociation within the range covered. The effect of dissociation can be estimated using formulas discussed in reference [9]. The tables are computed from the virial equation:

$$Z = 1 + BP + CP^2 + DP^3$$

The coefficients B and C were calculated from the Lennard-Jones potential, using intermolecular force constants as parameters.

The parameter values for the second virial coefficients, B, were obtained by a graphical method which permits the simultaneous fit of data on the Joule-Thomson coefficient and on the pressure dependence of PV/RT, [1] - [6], internal energy, specific heat, and velocity of sound. The experimental third virials, C, were fitted using the second virial coefficient parameters only for a cluster of two and graphically determined values of the parameters for a cluster of three, according with the fact that the equilibrium constant for the formation of a cluster of three is $K_3 = (2B^2 - C/2)/(RT)^2$. The modification of the usual Lennard-Jones [7] treatment was undertaken in an effort to provide a more applicable model for oxygen, than is afforded by the unmodified theory.

Reliability of the table

The compressibility values tabulated herein are considered reliable to approximately one unit in next to the last place tabulated for most entries. Below 300°K the reliability decreases to about 3 units in the next to the last tabulated place. Figures 1 and 2 show the departures of experimental compressibilities from the tabulated values.

Interpolation

The validity of linear interpolation in both temperature and pressure varies throughout the table. The error produced thereby does not, in general, exceed one-eighth of the second difference. First differences in the temperature direction are given for assistance in interpolation where they seem helpful. The pressure intervals have been chosen to facilitate three and four point Lagrangian interpolation [8] in each decade. Use of this method is recommended when errors produced by linear interpolation approach the uncertainty of the table.

Conversion Factors

The compressibility factor is dimensionless. Values of the gas constant R are listed for frequently used units in order to facilitate the use of this table in calculating, by means of the equation Z = PV/RT, the pressure P, the specific volume V, (or the denisyt $\rho = 1/V$), or the temperature T, when any two of these are known. The values given below are based on a molecular weight of 32.000.

Values of R for Oxygen

For temperatures in degrees Kelvin

ρ \ P	atm	Kg/cm^2	mm Hg	lb/in^2
g/cm^3	2.56427	2.64948	1948.85	37.6847
$mole/cm^3$	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0410756	0.0424403	31.2175	0.603647
lb $mole/ft^3$	1.31442	1.35809	998.959	19.3167

For temperatures in degrees Rankine

ρ \ P	atm	Kg/cm^2	mm Hg	lb/in^2
g/cm^3	1.42459	1.47193	1082.69	20.9358
$mole/cm^3$	45.5870	47.1017	34646.1	669.947
mole/liter	0.0455857	0.0471004	34.6451	0.669928
lb/ft^3	0.0228197	0.0235780	17.3430	0.335359
lb $mole/ft^3$	0.730231	0.754495	554.976	10.7315

REFERENCES

[1] G. P. Baxter and H. W. Starkweather, The density of oxygen and its compressibility below one atmosphere, Proc. Nat. Acad. Sci. 12, 699-703(1926).

[2] W. Heuse and J. Otto, Über eine Neubestimmung des Grenzwertes der Ausdehnungs-und Spannungskoeffizienten von Helium, Wasserstoff, und Stickstoff, Ann. Physik, series 2, 5, 1012(1929).

[3] L. Holborn and J. Otto, Über die Isothermen einiger Gase zwischen 400° und -183°, Z. Physik, 33, 1(1925).

[4] H. Kammerlingh Omnes and H. A. Kuypers, Isotherms of Oxygen at low temperatures, Commun. Lab. Leiden No. 169a (1925).

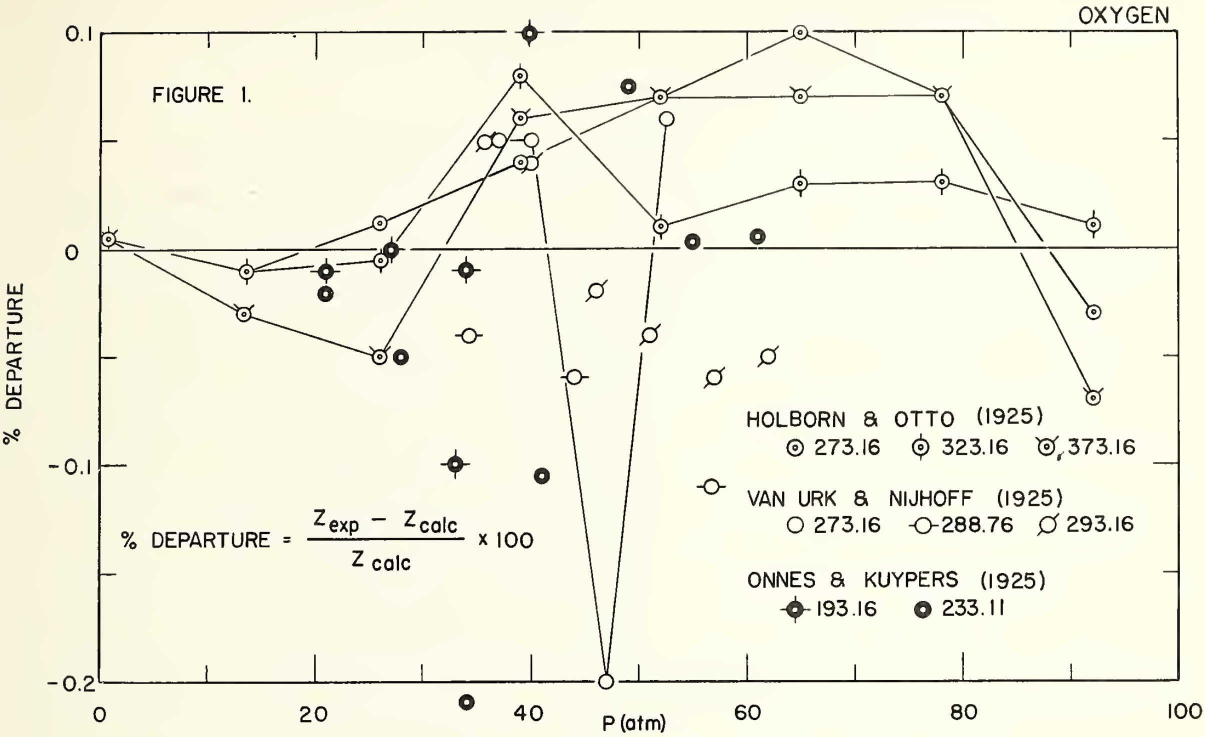
[5] G. P. Nijhoff and W. H. Keesom, Isotherms of diatomic substances and their binary mixtures, XXXIII, Isotherms of oxygen between -40° and -152.5° and pressures from 3 to 9 atmospheres, Commun. Lab. Leiden No. 179b (1925).

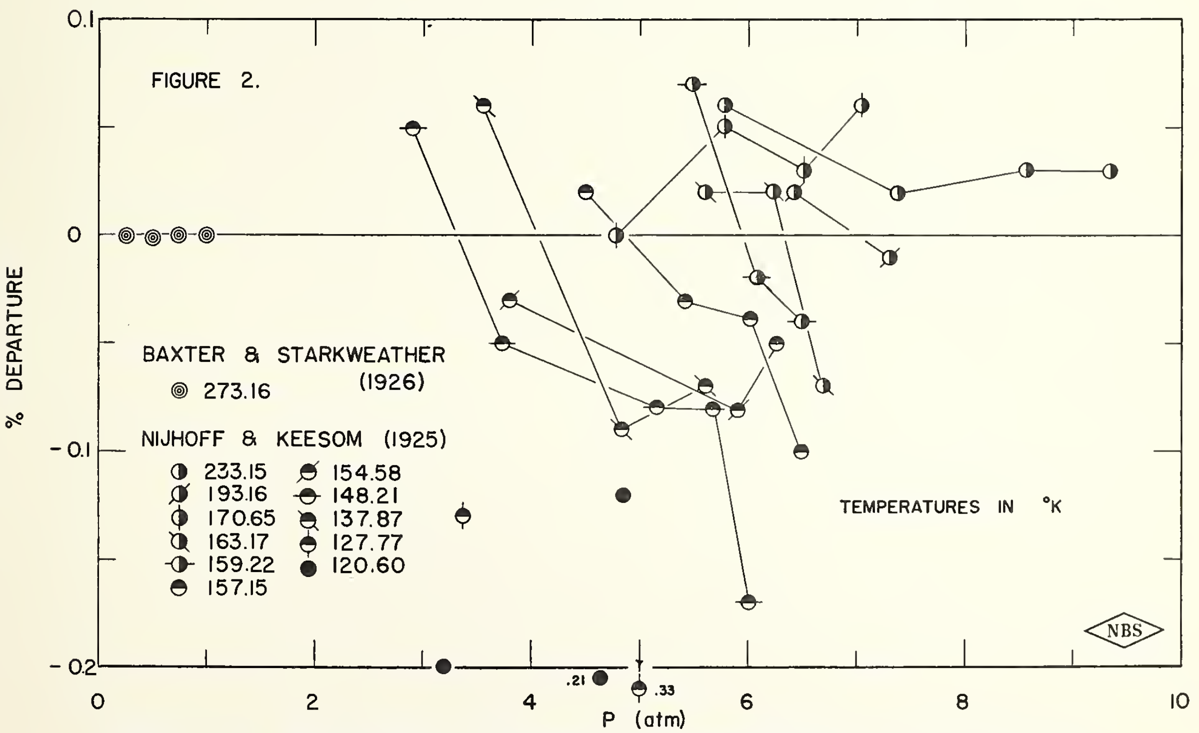
[6] A. Th. van Urk and G. P. Nijhoff, Isotherms of oxygen at 20°, 15.6°, and 0°, Commun. Lab. Leiden No. 169c (1925).

[7] R. B. Bird, E. L. Spotz, and J. O. Hirschfelder, The third virial coefficient for non-polar gases, J. Chem. Phys. 18, 1395-1402 (1950).

[8] "Tables of Lagrangian Interpolation Coefficients", Columbia University Press, New York, N. Y. (1944).

[9] H. W. Woolley, "The effect of dissociation on the thermodynamic properties of pure diatomic gases", Report No. 1884, National Bureau of Standards, October 15, 1952.





FIGURES 1 & 2. DEPARTURES OF EXPERIMENTAL COMPRESSIBILITIES FROM TABLE 9.20

U. S. Department of Commerce National Bureau of Standards

The NBS - NACA Tables of Thermal Properties of Gases

Table 9.22 Enthalpy and Entropy of Oxygen

$(H - E_0^0)/RT_0$, S/R

by

Harold W. Woolley

June 1953

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^0)/RT_0$

T °K	Pressure .01 atm		.1 atm		4 atm		7 atm		1 atm		T °R
100	1.2772	1282	1.2752	1285	1.2687	1294	1.2625	1300	1.254	132	180
110	1.4054	1281	1.4037	1284	1.3981	1292	1.3925	1298	1.3865	1310	198
120	1.5335	1283	1.5321	1284	1.5273	1290	1.5223	1296	1.5175	1302	216
130	1.6618	1282	1.6605	1283	1.6563	1288	1.6519	1293	1.6477	1298	234
140	1.7900	1282	1.7888	1284	1.7851	1287	1.7812	1293	1.7775	1295	252
150	1.9182	1281	1.9172	1282	1.9138	1286	1.9105	1288	1.9070	1292	270
160	2.0463	1282	2.0454	1283	2.0424	1285	2.0393	1289	2.0362	1292	288
170	2.1745	1282	2.1737	1283	2.1709	1286	2.1682	1288	2.1654	1290	306
180	2.3027	1282	2.3020	1282	2.2995	1284	2.2970	1286	2.2944	1289	324
190	2.4309	1283	2.4302	1284	2.4279	1286	2.4256	1288	2.4233	1290	342
200	2.5592	1282	2.5586	1282	2.5565	1284	2.5544	1285	2.5523	1287	360
210	2.6874	1283	2.6868	1284	2.6849	1285	2.6829	1287	2.6810	1288	378
220	2.8157	1284	2.8152	1284	2.8134	1286	2.8116	1287	2.8098	1288	396
230	2.9441	1284	2.9436	1285	2.9420	1285	2.9403	1287	2.9386	1288	414
240	3.0725	1287	3.0721	1286	3.0705	1288	3.0690	1288	3.0674	1289	432
250	3.2012	1286	3.2007	1286	3.1993	1287	3.1978	1288	3.1963	1290	450
260	3.3298	1288	3.3293	1289	3.3280	1289	3.3266	1290	3.3253	1291	468
270	3.4586	1289	3.4582	1289	3.4569	1290	3.4556	1291	3.4544	1291	486
280	3.5875	1291	3.5871	1291	3.5859	1292	3.5847	1293	3.5835	1294	504
290	3.7166	1293	3.7162	1293	3.7151	1294	3.7140	1294	3.7129	1295	522
300	3.8459	1295	3.8455	1296	3.8445	1296	3.8434	1297	3.8424	1297	540
310	3.9754	1297	3.9751	1297	3.9741	1298	3.9731	1298	3.9721	1299	558
320	4.1051	1300	4.1048	1300	4.1039	1300	4.1029	1302	4.1020	1302	576
330	4.2351	1303	4.2348	1303	4.2339	1304	4.2331	1304	4.2322	1304	594
340	4.3654	1306	4.3651	1306	4.3643	1307	4.3635	1307	4.3626	1308	612
350	4.4960	1309	4.4957	1310	4.4950	1309	4.4942	1310	4.4934	1311	630
360	4.6269	1313	4.6267	1313	4.6259	1314	4.6252	1314	4.6245	1314	648
370	4.7582	1316	4.7580	1316	4.7573	1316	4.7566	1317	4.7559	1317	666
380	4.8898	1320	4.8896	1320	4.8889	1321	4.8883	1321	4.8876	1321	684
390	5.0218	1324	5.0216	1324	5.0210	1324	5.0204	1324	5.0197	1326	702
400	5.1542	1327	5.1540	1327	5.1534	1328	5.1528	1328	5.1523	1328	720
410	5.2869	1332	5.2867	1332	5.2862	1332	5.2856	1333	5.2851	1333	738
420	5.4201	1336	5.4199	1336	5.4194	1336	5.4189	1337	5.4184	1337	756
430	5.5537	1340	5.5535	1340	5.5530	1341	5.5526	1340	5.5521	1341	774
440	5.6877	1345	5.6875	1346	5.6871	1345	5.6866	1346	5.6862	1346	792
450	5.8222		5.8221		5.8216		5.8212		5.8208		810

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^0)/RT_0$

T °K	Pressure: .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
450	5.8222	1349	5.8221	1349	5.8216	1350	5.8212	1349	5.8208	1349	810
460	5.9571	1353	5.9570	1353	5.9566	1353	5.9561	1354	5.9557	1354	828
470	6.0924	1358	6.0923	1358	6.0919	1358	6.0915	1359	6.0911	1359	846
480	6.2282	1362	6.2281	1362	6.2277	1362	6.2274	1362	6.2270	1363	864
490	6.3644	1367	6.3643	1367	6.3639	1368	6.3636	1368	6.3633	1367	882
500	6.5011	1371	6.5010	1371	6.5007	1371	6.5004	1371	6.5000	1372	900
510	6.6382	1376	6.6381	1376	6.6378	1376	6.6375	1376	6.6372	1377	918
520	6.7758	1380	6.7757	1380	6.7754	1380	6.7751	1381	6.7749	1380	936
530	6.9138	1385	6.9137	1385	6.9134	1386	6.9132	1385	6.9129	1386	954
540	7.0523	1389	7.0522	1389	7.0520	1389	7.0517	1390	7.0515	1389	972
550	7.1912	1394	7.1911	1394	7.1909	1394	7.1907	1394	7.1904	1395	990
560	7.3306	1398	7.3305	1398	7.3303	1398	7.3301	1398	7.3299	1398	1008
570	7.4704	1402	7.4703	1402	7.4701	1403	7.4699	1403	7.4697	1403	1026
580	7.6106	1407	7.6105	1407	7.6104	1407	7.6102	1407	7.6100	1407	1044
590	7.7513	1411	7.7512	1411	7.7511	1411	7.7509	1411	7.7507	1412	1062
600	7.8924	1415	7.8923	1416	7.8922	1415	7.8920	1416	7.8919	1415	1080
610	8.0339	1419	8.0339	1419	8.0337	1419	8.0336	1419	8.0334	1420	1098
620	8.1758	1423	8.1758	1423	8.1756	1423	8.1755	1423	8.1754	1423	1116
630	8.3181	1428	8.3181	1428	8.3179	1429	8.3178	1429	8.3177	1429	1134
640	8.4609	1431	8.4609	1431	8.4608	1431	8.4607	1431	8.4606	1431	1152
650	8.6040	1436	8.6040	1436	8.6039	1436	8.6038	1436	8.6037	1436	1170
660	8.7476	1439	8.7476	1439	8.7475	1439	8.7474	1439	8.7473	1440	1188
670	8.8915	1443	8.8915	1443	8.8914	1443	8.8913	1444	8.8913	1443	1206
680	9.0358	1447	9.0358	1447	9.0357	1447	9.0357	1447	9.0356	1447	1224
690	9.1805	1450	9.1805	1450	9.1804	1450	9.1804	1450	9.1803	1451	1242
700	9.3255	1454	9.3255	1454	9.3254	1455	9.3254	1454	9.3254	1454	1260
710	9.4709	1458	9.4709	1458	9.4709	1458	9.4708	1458	9.4708	1458	1278
720	9.6167	1461	9.6167	1461	9.6167	1461	9.6166	1462	9.6166	1462	1296
730	9.7628	1465	9.7628	1465	9.7628	1465	9.7628	1465	9.7628	1465	1314
740	9.9093	1468	9.9093	1468	9.9093	1468	9.9093	1468	9.9093	1468	1332
750	10.0561	1471	10.0561	1471	10.0561	1471	10.0561	1471	10.0561	1471	1350
760	10.2032	1475	10.2032	1475	10.2032	1475	10.2032	1475	10.2032	1476	1368
770	10.3507	1478	10.3507	1478	10.3507	1478	10.3507	1479	10.3508	1478	1386
780	10.4985	1481	10.4985	1481	10.4985	1481	10.4986	1481	10.4986	1481	1404
790	10.6466	1484	10.6466	1484	10.6466	1485	10.6467	1484	10.6467	1484	1422
800	10.7950		10.7950		10.7951		10.7951		10.7951		1440

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	Pressure: .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
800	10.7950	7464	10.7950	7464	10.7951	7464	10.7951	7465	10.7951	7465	1440
850	11.5414	7532	11.5414	7532	11.5415	7531	11.5416	7531	11.5416	7533	1530
900	12.2946	7595	12.2946	7595	12.2946	7597	12.2947	7597	12.2949	7596	1620
950	13.0541	7652	13.0541	7653	13.0543	7652	13.0544	7653	13.0545	7653	1710
1000	13.8193	7703	13.8194	7703	13.8195	7703	13.8197	7703	13.8198	7704	1800
1050	14.5896	7751	14.5897	7751	14.5898	7752	14.5900	7751	14.5902	7751	1890
1100	15.3647	7795	15.3648	7795	15.3650	7795	15.3651	7796	15.3653	7796	1980
1150	16.1442	7836	16.1443	7836	16.1445	7836	16.1447	7836	16.1449	7836	2070
1200	16.9278	7873	16.9279	7873	16.9281	7873	16.9283	7873	16.9285	7874	2160
1250	17.7151	7908	17.7152	7908	17.7154	7908	17.7156	7909	17.7159	7908	2250
1300	18.5059	7943	18.5060	7943	18.5062	7943	18.5065	7943	18.5067	7944	2340
1350	19.3002	7974	19.3003	7974	19.3005	7975	19.3008	7974	19.3011	7974	2430
1400	20.0976	8005	20.0977	8005	20.0980	8005	20.0982	8005	20.0985	8005	2520
1450	20.8981	8035	20.8982	8035	20.8985	8035	20.8987	8036	20.8990	8035	2610
1500	21.7016	8064	21.7017	8064	21.7020	8064	21.7023	8064	21.7025	8065	2700
1550	22.5080	8091	22.5081	8091	22.5084	8091	22.5087	8091	22.5090	8091	2790
1600	23.3171	8119	23.3172	8119	23.3175	8119	23.3178	8119	23.3181	8119	2880
1650	24.1290	8147	24.1291	8147	24.1294	8147	24.1297	8147	24.1300	8147	2970
1700	24.9437	8172	24.9438	8172	24.9441	8172	24.9444	8172	24.9447	8173	3060
1750	25.7609	8200	25.7610	8200	25.7613	8200	25.7616	8201	25.7620	8200	3150
1800	26.5809	8227	26.5810	8227	26.5813	8227	26.5817	8227	26.5820	8227	3240
1850	27.4036	8252	27.4037	8252	27.4040	8252	27.4044	8252	27.4047	8252	3330
1900	28.2288	8277	28.2289	8277	28.2292	8278	28.2296	8277	28.2299	8277	3420
1950	29.0565	8304	29.0566	8304	29.0570	8304	29.0573	8304	29.0576	8304	3510
2000	29.8869	8329	29.8870	8329	29.8874	8329	29.8877	8329	29.8880	8330	3600
2050	30.7198	8356	30.7199	8356	30.7203	8356	30.7206	8356	30.7210	8356	3690
2100	31.5554	8381	31.5555	8381	31.5559	8381	31.5562	8381	31.5566	8381	3780
2150	32.3935	8406	32.3936	8406	32.3940	8406	32.3943	8406	32.3947	8406	3870
2200	33.2341	8430	33.2342	8430	33.2346	8430	33.2349	8430	33.2353	8430	3960
2250	34.0771	8456	34.0772	8456	34.0776	8456	34.0779	8456	34.0783	8456	4050
2300	34.9227		34.9228		34.9232		34.9235		34.9239		4140

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
2300	34.9227	8482	34.9228	8482	34.9232	8482	34.9235	8483	34.9239	8482	4140
2350	35.7709	8508	35.7710	8508	35.7714	8508	35.7718	8508	35.7721	8508	4230
2400	36.6217	8530	36.6218	8530	36.6222	8530	36.6226	8530	36.6229	8530	4320
2450	37.4747	8555	37.4748	8555	37.4752	8555	37.4756	8555	37.4759	8555	4410
2500	38.3302	8580	38.3303	8580	38.3307	8580	38.3311	8580	38.3314	8580	4500
2550	39.1882	8605	39.1883	8605	39.1887	8605	39.1891	8605	39.1894	8606	4590
2600	40.0487	8627	40.0488	8627	40.0492	8627	40.0496	8627	40.0500	8627	4680
2650	40.9114	8651	40.9115	8651	40.9119	8651	40.9123	8651	40.9127	8651	4770
2700	41.7765	8675	41.7766	8675	41.7770	8675	41.7774	8675	41.7778	8675	4860
2750	42.6440	8698	42.6441	8698	42.6445	8698	42.6449	8698	42.6453	8698	4950
2800	43.5138	8720	43.5139	8720	43.5143	8720	43.5147	8720	43.5151	8720	5040
2850	44.3858	8743	44.3859	8743	44.3863	8743	44.3867	8743	44.3871	8743	5130
2900	45.2601	8765	45.2602	8765	45.2606	8765	45.2610	8765	45.2614	8765	5220
2950	46.1366	8786	46.1367	8786	46.1371	8786	46.1375	8786	46.1379	8786	5310
3000	47.0152		47.0153		47.0157		47.0161		47.0165		5400

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
100	1.254	132							180
110	1.3865	1310	1.315	148					198
120	1.5175	1302	1.4628	1393	1.394	156			216
130	1.6477	1298	1.6021	1360	1.5505	1449	1.505	144	234
140	1.7775	1295	1.7381	1340	1.6954	1400	1.649	147	252
150	1.9070	1292	1.8721	1329	1.8354	1373	1.7963	1427	270
160	2.0362	1292	2.0050	1324	1.9727	1356	1.9390	1395	288
170	2.1654	1290	2.1374	1315	2.1083	1344	2.0785	1375	306
180	2.2944	1289	2.2689	1311	2.2427	1335	2.2160	1360	324
190	2.4233	1290	2.4000	1308	2.3762	1329	2.3520	1351	342
200	2.5523	1287	2.5308	1305	2.5091	1322	2.4871	1340	360
210	2.6810	1288	2.6613	1302	2.6413	1319	2.6211	1334	378
220	2.8098	1288	2.7915	1302	2.7732	1315	2.7545	1329	396
230	2.9386	1288	2.9217	1300	2.9047	1312	2.8874	1325	414
240	3.0674	1289	3.0517	1300	3.0359	1310	3.0199	1323	432
250	3.1963	1290	3.1817	1299	3.1669	1310	3.1522	1319	450
260	3.3253	1291	3.3116	1299	3.2979	1308	3.2841	1318	468
270	3.4544	1291	3.4415	1301	3.4287	1309	3.4159	1315	486
280	3.5835	1294	3.5716	1301	3.5596	1308	3.5474	1317	504
290	3.7129	1295	3.7017	1302	3.6904	1309	3.6791	1317	522
300	3.8424	1297	3.8319	1303	3.8213	1309	3.8108	1316	540
310	3.9721	1299	3.9622	1305	3.9522	1312	3.9424	1316	558
320	4.1020	1302	4.0927	1307	4.0834	1313	4.0740	1319	576
330	4.2322	1304	4.2234	1310	4.2147	1314	4.2059	1320	594
340	4.3626	1308	4.3544	1312	4.3461	1317	4.3379	1322	612
350	4.4934	1311	4.4856	1315	4.4778	1320	4.4701	1323	630
360	4.6245	1314	4.6171	1319	4.6098	1322	4.6024	1327	648
370	4.7559	1317	4.7490	1321	4.7420	1326	4.7351	1329	666
380	4.8876	1321	4.8811	1325	4.8746	1328	4.8680	1332	684
390	5.0197	1326	5.0136	1328	5.0074	1332	5.0012	1337	702
400	5.1523	1328	5.1464	1332	5.1406	1335	5.1349	1338	720
410	5.2851	1333	5.2796	1336	5.2741	1339	5.2687	1342	738
420	5.4184	1337	5.4132	1340	5.4080	1343	5.4029	1346	756
430	5.5521	1341	5.5472	1344	5.5423	1346	5.5375	1349	774
440	5.6862	1346	5.6816	1348	5.6769	1352	5.6724	1354	792
450	5.8208		5.8164		5.8121		5.8078		810

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^0)/RT_0$

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
450	5.8208	1349	5.8164	1352	5.8121	1354	5.8078	1357	810
460	5.9557	1354	5.9516	1357	5.9475	1359	5.9435	1361	828
470	6.0911	1359	6.0873	1361	6.0834	1363	6.0796	1366	846
480	6.2270	1363	6.2234	1365	6.2197	1367	6.2162	1369	864
490	6.3633	1367	6.3599	1369	6.3564	1372	6.3531	1374	882
500	6.5000	1372	6.4968	1374	6.4936	1376	6.4905	1378	900
510	6.6372	1377	6.6342	1378	6.6312	1380	6.6283	1382	918
520	6.7749	1380	6.7720	1383	6.7692	1385	6.7665	1386	936
530	6.9129	1386	6.9103	1387	6.9077	1389	6.9051	1391	954
540	7.0515	1389	7.0490	1391	7.0466	1393	7.0442	1395	972
550	7.1904	1395	7.1881	1397	7.1859	1397	7.1837	1399	990
560	7.3299	1398	7.3278	1400	7.3256	1402	7.3236	1403	1008
570	7.4697	1403	7.4678	1404	7.4658	1405	7.4639	1407	1026
580	7.6100	1407	7.6082	1409	7.6063	1411	7.6046	1412	1044
590	7.7507	1412	7.7491	1412	7.7474	1414	7.7458	1415	1062
600	7.8919	1415	7.8903	1417	7.8888	1418	7.8873	1420	1080
610	8.0334	1420	8.0320	1421	8.0306	1422	8.0293	1423	1098
620	8.1754	1423	8.1741	1425	8.1728	1426	8.1716	1427	1116
630	8.3177	1429	8.3166	1429	8.3154	1431	8.3143	1432	1134
640	8.4606	1431	8.4595	1433	8.4585	1433	8.4575	1435	1152
650	8.6037	1436	8.6028	1437	8.6018	1439	8.6010	1440	1170
660	8.7473	1440	8.7465	1441	8.7457	1441	8.7450	1442	1188
670	8.8913	1443	8.8906	1444	8.8898	1446	8.8892	1447	1206
680	9.0356	1447	9.0350	1448	9.0344	1449	9.0339	1450	1224
690	9.1803	1451	9.1798	1452	9.1793	1452	9.1789	1453	1242
700	9.3254	1454	9.3250	1455	9.3245	1457	9.3242	1457	1260
710	9.4708	1458	9.4705	1459	9.4702	1460	9.4699	1461	1278
720	9.6166	1462	9.6164	1462	9.6162	1463	9.6160	1464	1296
730	9.7628	1465	9.7626	1466	9.7625	1467	9.7624	1468	1314
740	9.9093	1468	9.9092	1469	9.9092	1470	9.9092	1471	1332
750	10.0561	1471	10.0561	1473	10.0562	1473	10.0563	1474	1350
760	10.2032	1476	10.2034	1476	10.2035	1477	10.2037	1477	1368
770	10.3508	1478	10.3510	1479	10.3512	1479	10.3514	1481	1386
780	10.4986	1481	10.4989	1482	10.4991	1483	10.4995	1483	1404
790	10.6467	1484	10.6471	1485	10.6474	1486	10.6478	1487	1422
800	10.7951		10.7956		10.7960		10.7965		1440

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^0)/RT_0$

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
800	10.7951	7465	10.7956	7468	10.7960	7471	10.7965	7475	1440
850	11.5416	7533	11.5424	7536	11.5431	7539	11.5440	7541	1530
900	12.2949	7596	12.2960	7598	12.2970	7601	12.2981	7603	1620
950	13.0545	7653	13.0558	7655	13.0571	7657	13.0584	7659	1710
1000	13.8198	7704	13.8213	7706	13.8228	7708	13.8243	7710	1800
1050	14.5902	7751	14.5919	7753	14.5936	7755	14.5953	7757	1890
1100	15.3653	7796	15.3672	7797	15.3691	7799	15.3710	7801	1980
1150	16.1449	7836	16.1469	7838	16.1490	7839	16.1511	7840	2070
1200	16.9285	7874	16.9307	7875	16.9329	7876	16.9351	7878	2160
1250	17.7159	7908	17.7182	7910	17.7205	7911	17.7229	7912	2250
1300	18.5067	7944	18.5092	7944	18.5116	7946	18.5141	7947	2340
1350	19.3011	7974	19.3036	7976	19.3062	7976	19.3088	7977	2430
1400	20.0985	8005	20.1012	8006	20.1038	8007	20.1065	8008	2520
1450	20.8990	8035	20.9018	8036	20.9045	8037	20.9073	8038	2610
1500	21.7025	8065	21.7054	8065	21.7082	8066	21.7111	8067	2700
1550	22.5090	8091	22.5119	8092	22.5148	8093	22.5178	8093	2790
1600	23.3181	8119	23.3211	8120	23.3241	8121	23.3271	8121	2880
1650	24.1300	8147	24.1331	8148	24.1362	8148	24.1392	8149	2970
1700	24.9447	8173	24.9479	8173	24.9510	8173	24.9541	8174	3060
1750	25.7620	8200	25.7652	8200	25.7683	8202	25.7715	8202	3150
1800	26.5820	8227	26.5852	8228	26.5885	8228	26.5917	8229	3240
1850	27.4047	8252	27.4080	8253	27.4113	8253	27.4146	8253	3330
1900	28.2299	8277	28.2333	8277	28.2366	8278	28.2399	8279	3420
1950	29.0576	8304	29.0610	8305	29.0644	8305	29.0678	8305	3510
2000	29.8880	8330	29.8915	8329	29.8949	8330	29.8983	8331	3600
2050	30.7210	8356	30.7244	8357	30.7279	8357	30.7314	8357	3690
2100	31.5566	8381	31.5601	8381	31.5636	8381	31.5671	8382	3780
2150	32.3947	8406	32.3982	8407	32.4017	8407	32.4053	8407	3870
2200	33.2353	8430	33.2389	8430	33.2424	8431	33.2460	8431	3960
2250	34.0783	8456	34.0819	8456	34.0855	8457	34.0891	8457	4050
2300	34.9239		34.9275		34.9312		34.9348		4140

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
2300	34.9239	8482	34.9275	8483	34.9312	8482	34.9348	8483	4140
2350	35.7721	8508	35.7758	8508	35.7794	8509	35.7831	8509	4230
2400	36.6229	8530	36.6266	8530	36.6303	8530	36.6340	8530	4320
2450	37.4759	8555	37.4796	8556	37.4833	8556	37.4870	8556	4410
2500	38.3314	8580	38.3352	8580	38.3389	8580	38.3426	8581	4500
2550	39.1894	8606	39.1932	8605	39.1969	8606	39.2007	8606	4590
2600	40.0500	8627	40.0537	8627	40.0575	8627	40.0613	8627	4680
2650	40.9127	8651	40.9164	8652	40.9202	8652	40.9240	8652	4770
2700	41.7778	8675	41.7816	8675	41.7854	8675	41.7892	8675	4860
2750	42.6453	8698	42.6491	8698	42.6529	8698	42.6567	8699	4950
2800	43.5151	8720	43.5189	8720	43.5227	8721	43.5266	8720	5040
2850	44.3871	8743	44.3909	8744	44.3948	8743	44.3986	8744	5130
2900	45.2614	8765	45.2653	8765	45.2691	8766	45.2730	8765	5220
2950	46.1379	8786	46.1418	8786	46.1457	8786	46.1495	8787	5310
3000	47.0165		47.0204		47.0243		47.0282		5400

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^0)/RT_0$

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
130	1.505	144							234
140	1.649	147							252
150	1.7963	1427							270
160	1.9390	1395	1.48	23					288
170	2.0785	1375	1.711	194	1.16	33			306
180	2.2160	1360	1.905	177	1.490	261	.94	41	324
190	2.3520	1351	2.082	166	1.751	221	1.346	313	342
200	2.4871	1340	2.248	158	1.972	198	1.659	257	360
210	2.6211	1334	2.406	153	2.170	182	1.916	222	378
220	2.7545	1329	2.559	150	2.352	172	2.138	202	396
230	2.8874	1325	2.709	142	2.524	165	2.340	186	414
240	3.0199	1323	2.851	150	2.689	160	2.526	177	432
250	3.1522	1319	3.001	143	2.849	156	2.703	169	450
260	3.2841	1318	3.144	142	3.005	152	2.872	163	468
270	3.4159	1315	3.286	140	3.157	150	3.035	160	486
280	3.5474	1317	3.426	140	3.307	148	3.195	156	504
290	3.6791	1317	3.566	139	3.455	147	3.351	154	522
300	3.8108	1316	3.705	138	3.602	145	3.505	151	540
310	3.9424	1316	3.843	138	3.747	144	3.656	150	558
320	4.0740	1319	3.981	138	3.891	143	3.806	148	576
330	4.2059	1320	4.119	137	4.034	142	3.954	147	594
340	4.3379	1322	4.256	137	4.176	142	4.101	147	612
350	4.4701	1323	4.393	137	4.318	142	4.248	146	630
360	4.6024	1327	4.530	137	4.460	141	4.394	145	648
370	4.7351	1329	4.667	137	4.601	141	4.539	144	666
380	4.8680	1332	4.804	137	4.742	140	4.683	144	684
390	5.0012	1337	4.941	137	4.882	141	4.827	144	702
400	5.1349	1338	5.078	137	5.023	140	4.971	143	720
410	5.2687	1342	5.215	137	5.163	141	5.114	143	738
420	5.4029	1346	5.352	138	5.304	140	5.257	143	756
430	5.5375	1349	5.490	138	5.444	141	5.400	143	774
440	5.6724	1354	5.628	138	5.585	140	5.543	144	792
450	5.8078		5.766		5.725		5.687		810

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	10 atm	Δ	40 atm	Δ	70 atm	Δ	100 atm	Δ	T °R
450	5.8078	1357	5.766	138	5.725	141	5.687	143	810
460	5.9435	1361	5.904	138	5.866	141	5.830	143	828
470	6.0796	1366	6.042	139	6.007	141	5.973	143	846
480	6.2162	1369	6.181	139	6.148	141	6.116	143	864
490	6.3531	1374	6.320	140	6.289	142	6.259	144	882
500	6.4905	1378	6.460	140	6.431	141	6.403	143	900
510	6.6283	1382	6.600	140	6.572	142	6.546	144	918
520	6.7665	1386	6.740	140	6.714	142	6.690	144	936
530	6.9051	1391	6.880	141	6.856	143	6.834	144	954
540	7.0442	1395	7.021	141	6.999	143	6.978	144	972
550	7.1837	1399	7.162	141	7.142	143	7.122	145	990
560	7.3236	1403	7.303	142	7.285	143	7.267	145	1008
570	7.4639	1407	7.445	143	7.428	144	7.412	145	1026
580	7.6046	1412	7.588	142	7.572	144	7.557	145	1044
590	7.7458	1415	7.730	143	7.716	144	7.702	146	1062
600	7.8873	1420	7.873	143	7.860	144	7.848	146	1080
610	8.0293	1423	8.016	144	8.004	145	7.994	146	1098
620	8.1716	1427	8.160	144	8.149	145	8.140	146	1116
630	8.3143	1432	8.304	144	8.294	146	8.286	147	1134
640	8.4575	1435	8.448	145	8.440	146	8.433	146	1152
650	8.6010	1440	8.593	145	8.586	146	8.579	148	1170
660	8.7450	1442	8.738	145	8.732	146	8.727	147	1188
670	8.8892	1447	8.883	146	8.878	147	8.874	148	1206
680	9.0339	1450	9.029	146	9.025	147	9.022	147	1224
690	9.1789	1453	9.175	146	9.172	147	9.169	149	1242
700	9.3242	1457	9.321	147	9.319	148	9.318	148	1260
710	9.4699	1461	9.468	147	9.467	148	9.466	149	1278
720	9.6160	1464	9.615	147	9.615	148	9.615	149	1296
730	9.7624	1468	9.762	148	9.763	148	9.764	149	1314
740	9.9092	1471	9.910	148	9.911	149	9.913	150	1332
750	10.0563	1474	10.058	148	10.060	149	10.063	149	1350
760	10.2037	1477	10.206	148	10.209	149	10.212	150	1368
770	10.3514	1481	10.354	149	10.358	149	10.362	151	1386
780	10.4995	1483	10.503	149	10.507	150	10.513	150	1404
790	10.6478	1487	10.652	150	10.657	150	10.663	151	1422
800	10.7965		10.802		10.807		10.814		1440

Table 9.22/1 Enthalpy of Molecular Oxygen $(H - E_0^o)/RT_0$

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
800	10.797		10.802		10.807		10.814		1440
		1501		1507		1514		1519	
900	12.298		12.309		12.321		12.333		1620
		1526		1531		1536		1541	
1000	13.824		13.840		13.857		13.874		1800
		1547		1551		1554		1557	
1100	15.371		15.391		15.411		15.431		1980
		1564		1567		1570		1573	
1200	16.935		16.958		16.981		17.004		2160
		1579		1581		1584		1587	
1300	18.514		18.539		18.565		18.591		2340
		1593		1595		1596		1598	
1400	20.107		20.134		20.161		20.189		2520
		1604		1606		1608		1610	
1500	21.711		21.740		21.769		21.799		2700
		1616		1618		1619		1620	
1600	23.327		23.358		23.388		23.419		2880
		1627		1628		1630		1631	
1700	24.954		24.986		25.018		25.050		3060
		1638		1639		1640		1641	
1800	26.592		26.625		26.658		26.691		3240
		1648		1649		1650		1651	
1900	28.240		28.274		28.308		28.342		3420
		1658		1659		1660		1661	
2000	29.898		29.933		29.968		30.003		3600
		1669		1669		1670		1671	
2100	31.567		31.602		31.638		31.674		3780
		1679		1680		1680		1681	
2200	33.246		33.282		33.318		33.355		3960
		1689		1689		1690		1690	
2300	34.935		34.971		35.008		35.045		4140
		1699		1700		1700		1700	
2400	36.634		36.671		36.708		36.745		4320
		1709		1709		1710		1710	
2500	38.343		38.380		38.418		38.455		4500
		1718		1719		1719		1720	
2600	40.061		40.099		40.137		40.175		4680
		1728		1728		1729		1729	
2700	41.789		41.827		41.866		41.904		4860
		1738		1738		1738		1739	
2800	43.527		43.565		43.604		43.643		5040
		1746		1747		1747		1747	
2900	45.273		45.312		45.351		45.390		5220
		1755		1755		1756		1756	
3000	47.028		47.067		47.107		47.146		5400

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
100	25.4396	3337	23.1336	3345	21.7357	3372	21.1638	3404	20.794	344	180
110	25.7733	3049	23.4681	3054	22.0729	3072	21.5042	3092	21.1381	3113	198
120	26.0782	2802	23.7735	2806	22.3801	2821	21.8134	2833	21.4494	2848	216
130	26.3584	2595	24.0541	2598	22.6622	2607	22.0967	2618	21.7342	2627	234
140	26.6179	2417	24.3139	2419	22.9229	2426	22.3585	2433	21.9969	2442	252
150	26.8596	2259	24.5558	2261	23.1655	2267	22.6018	2274	22.2411	2279	270
160	27.0855	2123	24.7819	2124	23.3922	2129	22.8292	2134	22.4690	2138	288
170	27.2978	2002	24.9943	2003	23.6051	2007	23.0426	2010	22.6828	2016	306
180	27.4980	1894	25.1946	1896	23.8058	1898	23.2436	1902	22.8844	1904	324
190	27.6874	1796	25.3842	1796	23.9956	1799	23.4338	1802	23.0748	1805	342
200	27.8670	1710	25.5638	1711	24.1755	1713	23.6140	1715	23.2553	1717	360
210	28.0380	1631	25.7349	1631	24.3468	1633	23.7855	1634	23.4270	1636	378
220	28.2011	1559	25.8980	1559	24.5101	1561	23.9489	1563	23.5906	1564	396
230	28.3570	1493	26.0539	1494	24.6662	1495	24.1052	1496	23.7470	1498	414
240	28.5063	1433	26.2033	1433	24.8157	1434	24.2548	1435	23.8968	1437	432
250	28.6496	1378	26.3466	1378	24.9591	1380	24.3983	1381	24.0405	1381	450
260	28.7874	1328	26.4844	1329	25.0971	1329	24.5364	1330	24.1786	1331	468
270	28.9202	1280	26.6173	1280	25.2300	1281	24.6694	1282	24.3117	1283	486
280	29.0482	1238	26.7453	1238	25.3581	1239	24.7976	1239	24.4400	1240	504
290	29.1720	1197	26.8691	1198	25.4820	1198	24.9215	1199	24.5640	1199	522
300	29.2917	1160	26.9889	1160	25.6018	1160	25.0414	1161	24.6839	1162	540
310	29.4077	1125	27.1049	1125	25.7178	1126	25.1575	1126	24.8001	1127	558
320	29.5202	1093	27.2174	1093	25.8304	1094	25.2701	1094	24.9128	1094	576
330	29.6295	1062	27.3267	1062	25.9398	1062	25.3795	1063	25.0222	1064	594
340	29.7357	1035	27.4329	1035	26.0460	1036	25.4858	1036	25.1286	1036	612
350	29.8392	1007	27.5364	1007	26.1496	1007	25.5894	1008	25.2322	1008	630
360	29.9399	982	27.6371	982	26.2503	983	25.6902	983	25.3330	983	648
370	30.0381	959	27.7353	959	26.3486	959	25.7885	959	25.4313	960	666
380	30.1340	936	27.8312	937	26.4445	936	25.8844	937	25.5273	937	684
390	30.2276	916	27.9249	916	26.5381	917	25.9781	917	25.6210	917	702
400	30.3192	896	28.0165	896	26.6298	896	26.0698	896	25.7127	896	720
410	30.4088	876	28.1061	876	26.7194	876	26.1594	877	25.8023	877	738
420	30.4964	859	28.1937	859	26.8070	859	26.2471	859	25.8900	860	756
430	30.5823	841	28.2796	841	26.8929	842	26.3330	841	25.9760	841	774
440	30.6664	826	28.3637	826	26.9771	826	26.4171	827	26.0601	827	792
450	30.7490		28.4463		27.0597		26.4998		26.1428		810

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
450	30.7490	810	28.4463	810	27.0597	810	26.4998	810	26.1428	810	810
460	30.8300	795	28.5273	795	27.1407	795	26.5808	796	26.2238	796	828
470	30.9095	780	28.6068	780	27.2202	780	26.6604	780	26.3034	780	846
480	30.9875	768	28.6848	769	27.2982	769	26.7384	768	26.3814	769	864
490	31.0643	754	28.7617	754	27.3751	754	26.8152	754	26.4583	754	882
500	31.1397	742	28.8371	742	27.4505	742	26.8906	743	26.5337	742	900
510	31.2139	730	28.9113	730	27.5247	730	26.9649	730	26.6079	731	918
520	31.2869	718	28.9843	718	27.5977	718	27.0379	718	26.6810	718	936
530	31.3587	707	29.0561	707	27.6695	707	27.1097	707	26.7528	707	954
540	31.4294	696	29.1268	696	27.7402	696	27.1804	697	26.8235	697	972
550	31.4990	686	29.1964	686	27.8098	687	27.2501	686	26.8932	686	990
560	31.5676	676	29.2650	676	27.8785	676	27.3187	676	26.9618	676	1008
570	31.6352	666	29.3326	666	27.9461	666	27.3863	666	27.0294	666	1026
580	31.7018	657	29.3992	657	28.0127	657	27.4529	657	27.0960	658	1044
590	31.7675	648	29.4649	648	28.0784	648	27.5186	648	27.1618	648	1062
600	31.8323	639	29.5297	639	28.1432	639	27.5834	639	27.2266	639	1080
610	31.8962	630	29.5936	630	28.2071	630	27.6473	631	27.2905	630	1098
620	31.9592	622	29.6566	622	28.2701	622	27.7104	622	27.3535	622	1116
630	32.0214	614	29.7188	614	28.3323	614	27.7726	614	27.4157	615	1134
640	32.0828	607	29.7802	607	28.3937	607	27.8340	607	27.4772	607	1152
650	32.1435	598	29.8409	598	28.4544	598	27.8947	598	27.5379	598	1170
660	32.2033	591	29.9007	591	28.5142	591	27.9545	591	27.5977	591	1188
670	32.2624	584	29.9598	584	28.5733	584	28.0136	584	27.6568	584	1206
680	32.3208	577	30.0182	577	28.6317	577	28.0720	577	27.7152	577	1224
690	32.3785	570	30.0759	570	28.6894	571	28.1297	570	27.7729	570	1242
700	32.4355	564	30.1329	564	28.7465	564	28.1867	565	27.8299	564	1260
710	32.4919	557	30.1893	557	28.8029	557	28.2432	557	27.8863	558	1278
720	32.5476	550	30.2450	550	28.8586	550	28.2989	550	27.9421	550	1296
730	32.6026	545	30.3000	545	28.9136	545	28.3539	545	27.9971	545	1314
740	32.6571	538	30.3545	538	28.9681	538	28.4084	538	28.0516	538	1332
750	32.7109	532	30.4083	532	29.0219	532	28.4622	532	28.1054	532	1350
760	32.7641	527	30.4615	527	29.0751	527	28.5154	527	28.1586	527	1368
770	32.8168	521	30.5142	521	29.1278	521	28.5681	521	28.2113	521	1386
780	32.8689	515	30.5663	515	29.1799	515	28.6202	515	28.2634	515	1404
790	32.9204	510	30.6178	510	29.2314	510	28.6717	510	28.3149	510	1422
800	32.9714		30.6688		29.2824		28.7227		28.3659		1440

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
800	32.9714	2472	30.6688	2472	29.2824	2472	28.7227	2472	28.3659	2473	1440
850	33.2186	2352	30.9160	2352	29.5296	2352	28.9699	2353	28.6132	2352	1530
900	33.4538	2243	31.1512	2243	29.7648	2243	29.2052	2243	28.8484	2243	1620
950	33.6781	2145	31.3755	2145	29.9891	2145	29.4295	2145	29.0727	2145	1710
1000	33.8926	2053	31.5900	2053	30.2036	2053	29.6440	2053	29.2872	2054	1800
1050	34.0979	1970	31.7953	1970	30.4089	1971	29.8493	1970	29.4926	1970	1890
1100	34.2949	1893	31.9923	1893	30.6060	1893	30.0463	1893	29.6896	1893	1980
1150	34.4842	1821	32.1816	1821	30.7953	1821	30.2356	1821	29.8789	1821	2070
1200	34.6663	1756	32.3637	1756	30.9774	1756	30.4177	1756	30.0610	1756	2160
1250	34.8419	1695	32.5393	1695	31.1530	1695	30.5933	1695	30.2366	1695	2250
1300	35.0114	1638	32.7088	1638	31.3225	1638	30.7628	1639	30.4061	1638	2340
1350	35.1752	1584	32.8726	1584	31.4863	1584	30.9267	1584	30.5699	1584	2430
1400	35.3336	1535	33.0310	1535	31.6447	1535	31.0851	1535	30.7283	1535	2520
1450	35.4871	1488	33.1845	1488	31.7982	1488	31.2386	1488	30.8818	1489	2610
1500	35.6359	1444	33.3333	1444	31.9470	1444	31.3874	1444	31.0307	1444	2700
1550	35.7803	1404	33.4777	1404	32.0914	1404	31.5318	1404	31.1751	1404	2790
1600	35.9207	1364	33.6181	1364	32.2318	1364	31.6722	1364	31.3155	1364	2880
1650	36.0571	1329	33.7545	1329	32.3682	1329	31.8086	1329	31.4519	1329	2970
1700	36.1900	1294	33.8874	1294	32.5011	1294	31.9415	1294	31.5848	1294	3060
1750	36.3194	1262	34.0168	1262	32.6305	1262	32.0709	1262	31.7142	1262	3150
1800	36.4456	1232	34.1430	1232	32.7567	1232	32.1971	1232	31.8404	1232	3240
1850	36.5688	1202	34.2662	1202	32.8799	1202	32.3203	1202	31.9636	1202	3330
1900	36.6890	1175	34.3864	1175	33.0001	1175	32.4405	1175	32.0838	1175	3420
1950	36.8065	1148	34.5039	1148	33.1176	1148	32.5580	1148	32.2013	1148	3510
2000	36.9213	1124	34.6187	1124	33.2324	1124	32.6728	1124	32.3161	1124	3600
2050	37.0337	1100	34.7311	1100	33.3448	1100	32.7852	1100	32.4285	1100	3690
2100	37.1437	1077	34.8411	1077	33.4548	1077	32.8952	1077	32.5385	1077	3780
2150	37.2514	1056	34.9488	1056	33.5625	1056	33.0029	1056	32.6462	1056	3870
2200	37.3570	1035	35.0544	1035	33.6681	1035	33.1085	1035	32.7518	1035	3960
2250	37.4605	1015	35.1579	1015	33.7716	1015	33.2120	1015	32.8553	1015	4050
2300	37.5620		35.2594		33.8731		33.3135		32.9568		4140

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure .01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
2300	37.5620	997	35.2594	997	33.8731	997	33.3135	997	32.9568	997	4140
2350	37.6617	978	35.3591	978	33.9728	978	33.4132	978	33.0565	978	4230
2400	37.7595	961	35.4569	961	34.0706	961	33.5110	961	33.1543	961	4320
2450	37.8556	945	35.5530	945	34.1667	945	33.6071	945	33.2504	945	4410
2500	37.9501	928	35.6475	928	34.2612	928	33.7016	928	33.3449	928	4500
2550	38.0429	912	35.7403	912	34.3540	912	33.7944	912	33.4377	912	4590
2600	38.1341	898	35.8315	898	34.4452	898	33.8856	898	33.5289	898	4680
2650	38.2239	884	35.9213	884	34.5350	884	33.9754	884	33.6187	884	4770
2700	38.3123	869	36.0097	869	34.6234	869	34.0638	869	33.7071	869	4860
2750	38.3992	856	36.0966	856	34.7103	856	34.1507	856	33.7940	856	4950
2800	38.4848	844	36.1822	844	34.7959	844	34.2363	844	33.8796	844	5040
2850	38.5692	830	36.2666	830	34.8803	830	34.3207	830	33.9640	830	5130
2900	38.6522	819	36.3496	819	34.9633	819	34.4037	819	34.0470	819	5220
2950	38.7341	807	36.4315	807	35.0452	807	34.4856	807	34.1289	807	5310
3000	38.8148		36.5122		35.1259		34.5663		34.2096		5400

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure 1 atm		4 atm		7 atm		10 atm		T °R
100	20.794	344							180
110	21.1381	3113							198
120	21.4494	2848	19.981	304					216
130	21.7342	2627	20.2851	2751	19.651	294			234
140	21.9969	2442	20.5602	2529	19.9448	2639	19.525	279	252
150	22.2411	2279	20.8131	2345	20.2087	2421	19.8036	2514	270
160	22.4690	2138	21.0476	2188	20.4508	2246	20.0550	2310	288
170	22.6828	2016	21.2664	2055	20.6754	2099	20.2860	2148	306
180	22.8844	1904	21.4719	1937	20.8853	1973	20.5008	2010	324
190	23.0748	1805	21.6656	1832	21.0826	1860	20.7018	1890	342
200	23.2553	1717	21.8488	1739	21.2686	1763	20.8908	1788	360
210	23.4270	1636	22.0227	1655	21.4449	1674	21.0696	1695	378
220	23.5906	1564	22.1882	1580	21.6123	1597	21.2391	1614	396
230	23.7470	1498	22.3462	1512	21.7720	1525	21.4005	1540	414
240	23.8968	1437	22.4974	1449	21.9245	1461	21.5545	1473	432
250	24.0405	1381	22.6423	1391	22.0706	1403	21.7018	1415	450
260	24.1786	1331	22.7814	1340	22.2109	1349	21.8433	1359	468
270	24.3117	1283	22.9154	1292	22.3458	1300	21.9792	1306	486
280	24.4400	1240	23.0446	1247	22.4758	1254	22.1098	1263	504
290	24.5640	1199	23.1693	1206	22.6012	1212	22.2361	1218	522
300	24.6839	1162	23.2899	1167	22.7224	1173	22.3579	1179	540
310	24.8001	1127	23.4066	1132	22.8397	1138	22.4758	1142	558
320	24.9128	1094	23.5198	1099	22.9535	1104	22.5900	1108	576
330	25.0222	1064	23.6297	1067	23.0639	1071	22.7008	1076	594
340	25.1286	1036	23.7364	1040	23.1710	1044	22.8084	1048	612
350	25.2322	1008	23.8404	1012	23.2754	1015	22.9132	1019	630
360	25.3330	983	23.9416	986	23.3769	989	23.0151	992	648
370	25.4313	960	24.0402	963	23.4758	966	23.1143	969	666
380	25.5273	937	24.1365	939	23.5724	942	23.2112	944	684
390	25.6210	917	24.2304	920	23.6666	921	23.3056	924	702
400	25.7127	896	24.3224	898	23.7587	902	23.3980	904	720
410	25.8023	877	24.4122	879	23.8489	880	23.4884	882	738
420	25.8900	860	24.5001	862	23.9369	864	23.5766	866	756
430	25.9760	841	24.5863	843	24.0233	845	23.6632	847	774
440	26.0601	827	24.6706	828	24.1078	830	23.7479	831	792
450	26.1428		24.7534		24.1908		23.8310		810

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
450	26.1428	810	24.7534	812	24.1908	813	23.8310	815	810
460	26.2238	796	24.8346	797	24.2721	798	23.9125	800	828
470	26.3034	780	24.9143	782	24.3519	783	23.9925	784	846
480	26.3814	769	24.9925	769	24.4302	771	24.0709	772	864
490	26.4583	754	25.0694	756	24.5073	757	24.1481	758	882
500	26.5337	742	25.1450	743	24.5830	744	24.2239	746	900
510	26.6079	731	25.2193	732	24.6574	733	24.2985	733	918
520	26.6810	718	25.2925	719	24.7307	720	24.3718	721	936
530	26.7528	707	25.3644	708	24.8027	709	24.4439	710	954
540	26.8235	697	25.4352	697	24.8736	698	24.5149	699	972
550	26.8932	686	25.5049	687	24.9434	688	24.5848	689	990
560	26.9618	676	25.5736	677	25.0122	678	24.6537	678	1008
570	27.0294	666	25.6413	667	25.0800	667	24.7215	668	1026
580	27.0960	658	25.7080	658	25.1467	659	24.7883	660	1044
590	27.1618	648	25.7738	649	25.2126	649	24.8543	650	1062
600	27.2266	639	25.8387	640	25.2775	641	24.9193	641	1080
610	27.2905	630	25.9027	631	25.3416	631	24.9834	632	1098
620	27.3535	622	25.9658	622	25.4047	623	25.0466	623	1116
630	27.4157	615	26.0280	615	25.4670	616	25.1089	616	1134
640	27.4772	607	26.0895	608	25.5286	608	25.1705	609	1152
650	27.5379	598	26.1503	598	25.5894	599	25.2314	599	1170
660	27.5977	591	26.2101	592	25.6493	592	25.2913	593	1188
670	27.6568	584	26.2693	584	25.7085	585	25.3506	585	1206
680	27.7152	577	26.3277	578	25.7670	578	25.4091	578	1224
690	27.7729	570	26.3855	570	25.8248	571	26.4669	572	1242
700	27.8299	564	26.4425	565	25.8819	564	25.5241	565	1260
710	27.8863	558	26.4990	557	25.9383	558	25.5806	558	1278
720	27.9421	550	26.5547	551	25.9941	551	25.6364	551	1296
730	27.9971	545	26.6098	545	26.0492	546	25.6915	546	1314
740	28.0516	538	26.6643	539	26.1038	538	25.7461	539	1332
750	28.1054	532	26.7182	532	26.1576	533	25.8000	533	1350
760	28.1586	527	26.7714	527	26.2109	528	25.8533	528	1368
770	28.2113	521	26.8241	522	26.2637	521	25.9061	522	1386
780	28.2634	515	26.8763	515	26.3158	516	25.9583	516	1404
790	28.3149	510	26.9278	510	26.3674	511	26.0099	511	1422
800	28.3659		26.9788		26.4185		26.0610		1440

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure: 1 atm	Δ	4 atm	Δ	7 atm	Δ	10 atm	Δ	T °R
800	28.3659	2473	26.9788	2474	26.4185	2474	26.0610	2475	1440
850	28.6132	2352	27.2262	2353	26.6659	2354	26.3085	2355	1530
900	28.8484	2243	27.4615	2244	26.9013	2245	26.5440	2246	1620
950	29.0727	2145	27.6859	2146	27.1258	2146	26.7686	2147	1710
1000	29.2872	2054	27.9005	2054	27.3404	2055	26.9833	2055	1800
1050	29.4926	1970	28.1059	1970	27.5459	1971	27.1888	1971	1890
1100	29.6896	1893	28.3029	1894	27.7430	1894	27.3859	1895	1980
1150	29.8789	1821	28.4923	1821	27.9324	1822	27.5754	1822	2070
1200	30.0610	1756	28.6744	1757	28.1146	1756	27.7576	1757	2160
1250	30.2366	1695	28.8501	1695	28.2902	1696	27.9333	1696	2250
1300	30.4061	1638	29.0196	1638	28.4598	1638	28.1029	1638	2340
1350	30.5699	1584	29.1834	1585	28.6236	1585	28.2667	1585	2430
1400	30.7283	1535	29.3419	1535	28.7821	1535	28.4252	1536	2520
1450	30.8818	1489	29.4954	1488	28.9356	1489	28.5788	1488	2610
1500	31.0307	1444	29.6442	1444	29.0845	1444	28.7276	1445	2700
1550	31.1751	1404	29.7886	1404	29.2289	1404	28.8721	1404	2790
1600	31.3155	1364	29.9290	1365	29.3693	1365	29.0125	1364	2880
1650	31.4519	1329	30.0655	1329	29.5058	1329	29.1489	1330	2970
1700	31.5848	1294	30.1984	1295	29.6387	1294	29.2819	1294	3060
1750	31.7142	1262	30.3279	1261	29.7681	1262	29.4113	1262	3150
1800	31.8404	1232	30.4540	1232	29.8943	1232	29.5375	1233	3240
1850	31.9636	1202	30.5772	1202	30.0175	1202	29.6608	1202	3330
1900	32.0838	1175	30.6974	1175	30.1377	1176	29.7810	1175	3420
1950	32.2013	1148	30.8149	1148	30.2553	1148	29.8985	1148	3510
2000	32.3161	1124	30.9297	1124	30.3701	1124	30.0133	1124	3600
2050	32.4285	1100	31.0421	1100	30.4825	1100	30.1257	1101	3690
2100	32.5385	1077	31.1521	1077	30.5925	1077	30.2358	1077	3780
2150	32.6462	1056	31.2598	1057	30.7002	1056	30.3435	1056	3870
2200	32.7518	1035	31.3655	1035	30.8058	1035	30.4491	1035	3960
2250	32.8553	1015	31.4690	1015	30.9093	1015	30.5526	1015	4050
2300	32.9568		31.5705		31.0108		30.6541		4140

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure 1 atm		4 atm		7 atm		10 atm		T °R
2300	32.9568	997	31.5705	997	31.0108	997	30.6541	997	4140
2350	33.0565	978	31.6702	978	31.1105	978	30.7538	978	4230
2400	33.1543	961	31.7680	961	31.2083	962	30.8516	961	4320
2450	33.2504	945	31.8641	945	31.3045	945	30.9477	945	4410
2500	33.3449	928	31.9586	928	31.3990	928	31.0422	929	4500
2550	33.4377	912	32.0514	912	31.4918	912	31.1351	912	4590
2600	33.5289	898	32.1426	898	31.5830	898	31.2263	898	4680
2650	33.6187	884	32.2324	884	31.6728	884	31.3161	884	4770
2700	33.7071	869	32.3208	869	31.7612	869	31.4045	869	4860
2750	33.7940	856	32.4077	856	31.8481	856	31.4914	856	4950
2800	33.8796	844	32.4933	844	31.9337	844	31.5770	844	5040
2850	33.9640	830	32.5777	830	32.0181	830	31.6614	830	5130
2900	34.0470	819	32.6607	819	32.1011	819	31.7444	819	5220
2950	34.1289	807	32.7426	807	32.1830	807	31.8263	807	5310
3000	34.2096		32.8233		32.2637		31.9070		5400

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
140	19.525	279							252
150	19.8036	2514							270
160	20.0550	2310	18.10	37					288
170	20.2860	2148	18.474	304	17.2	5.			306
180	20.5008	2010	18.778	261	17.74	38	16.7	6	324
190	20.7018	1890	19.0389	2320	18.121	310	17.30	44	342
200	20.8908	1788	19.2709	2113	18.431	263	17.74	34	360
210	21.0696	1695	19.4822	1949	18.694	232	18.084	282	378
220	21.2391	1614	19.6771	1820	18.926	209	18.366	245	396
230	21.4005	1540	19.8591	1707	19.135	192	18.611	217	414
240	21.5545	1473	20.0298	1616	19.327	178	18.828	196	432
250	21.7018	1415	20.1914	1531	19.505	167	19.024	182	450
260	21.8433	1359	20.3445	1461	19.672	157	19.206	169	468
270	21.9792	1306	20.4906	1396	19.829	149	19.375	158	486
280	22.1098	1263	20.6302	1339	19.978	142	19.533	150	504
290	22.2361	1218	20.7641	1287	20.120	136	19.683	142	522
300	22.3579	1179	20.8928	1239	20.2555	1300	19.825	136	540
310	22.4758	1142	21.0167	1195	20.3855	1248	19.961	130	558
320	22.5900	1108	21.1362	1156	20.5103	1204	20.091	125	576
330	22.7008	1076	21.2518	1119	20.6307	1161	20.216	119	594
340	22.8084	1048	21.3637	1087	20.7468	1126	20.335	117	612
350	22.9132	1019	21.4724	1053	20.8594	1087	20.4516	1120	630
360	23.0151	992	21.5777	1025	20.9681	1055	20.5636	1085	648
370	23.1143	969	21.6802	997	21.0736	1027	20.6721	1052	666
380	23.2112	944	21.7799	972	21.1763	997	20.7773	1021	684
390	23.3056	924	21.8771	948	21.2760	973	20.8794	995	702
400	23.3980	904	21.9719	926	21.3733	947	20.9789	967	720
410	23.4884	882	22.0645	904	21.4680	924	21.0756	943	738
420	23.5766	866	22.1549	883	21.5604	903	21.1699	920	756
430	23.6632	847	22.2432	864	21.6507	880	21.2619	898	774
440	23.7479	831	22.3296	849	21.7387	864	21.3517	878	792
450	23.8310		22.4145		21.8251		21.4395		810

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
450	23.8310	815	22.4145	830	21.8251	846	21.4395	860	810
460	23.9125	800	22.4975	813	21.9097	827	21.5255	840	828
470	23.9925	784	22.5788	797	21.9924	811	21.6095	823	846
480	24.0709	772	22.6585	785	22.0735	794	21.6918	807	864
490	24.1481	758	22.7370	769	22.1529	782	21.7725	792	882
500	24.2239	746	22.8139	756	22.2311	767	21.8517	777	900
510	24.2985	733	22.8895	744	22.3078	753	21.9294	763	918
520	24.3718	721	22.9639	730	22.3831	740	22.0057	748	936
530	24.4439	710	23.0369	719	22.4571	728	22.0805	736	954
540	24.5149	699	23.1088	708	22.5299	715	22.1541	724	972
550	24.5848	689	23.1796	696	22.6014	704	22.2265	712	990
560	24.6537	678	23.2492	686	22.6718	693	22.2977	699	1008
570	24.7215	668	23.3178	676	22.7411	683	22.3676	689	1026
580	24.7883	660	23.3854	665	22.8094	672	22.4365	679	1044
590	24.8543	650	23.4519	657	22.8766	663	22.5044	668	1062
600	24.9193	641	23.5176	647	22.9429	652	22.5712	659	1080
610	24.9834	632	23.5823	637	23.0081	643	22.6371	648	1098
620	25.0466	623	23.6460	630	23.0724	635	22.7019	639	1116
630	25.1089	616	23.7090	620	23.1359	626	22.7658	631	1134
640	25.1705	609	23.7710	614	23.1985	618	22.8289	623	1152
650	25.2314	599	23.8324	604	23.2603	608	22.8912	613	1170
660	25.2913	593	23.8928	597	23.3211	601	22.9525	605	1188
670	25.3506	585	23.9525	589	23.3812	594	23.0130	597	1206
680	25.4091	578	24.0114	583	23.4406	587	23.0727	591	1224
690	26.4669	572	24.0697	575	23.4993	578	23.1318	582	1242
700	25.5241	565	24.1272	568	23.5571	573	23.1900	576	1260
710	25.5806	558	24.1840	561	23.6144	564	23.2476	568	1278
720	25.6364	551	24.2401	555	23.6708	557	23.3044	561	1296
730	25.6915	546	24.2956	549	23.7265	553	23.3605	555	1314
740	25.7461	539	24.3505	542	23.7818	545	23.4160	548	1332
750	25.8000	533	24.4047	536	23.8363	539	23.4708	542	1350
760	25.8533	528	24.4583	531	23.8902	532	23.5250	536	1368
770	25.9061	522	24.5114	524	23.9434	528	23.5786	530	1386
780	25.9583	516	24.5638	519	23.9962	520	23.6316	523	1404
790	26.0099	511	24.6157	513	24.0482	517	23.6839	518	1422
800	26.0610		24.6670		24.0999		23.7357		1440

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
800	26.0610	2475	24.6670	2487	24.0999	2496	23.7357	2507	1440
850	26.3085	2355	24.9157	2364	24.3495	2374	23.9864	2382	1530
900	26.5440	2246	25.1521	2252	24.5869	2258	24.2246	2267	1620
950	26.7686	2147	25.3773	2153	24.8127	2160	24.4513	2165	1710
1000	26.9833	2055	25.5926	2060	25.0287	2065	24.6678	2070	1800
1050	27.1888	1971	25.7986	1977	25.2352	1982	24.8748	1985	1890
1100	27.3859	1895	25.9963	1898	25.4334	1902	25.0733	1907	1980
1150	27.5754	1822	26.1861	1824	25.6236	1828	25.2640	1831	2070
1200	27.7576	1757	26.3685	1761	25.8064	1763	25.4471	1766	2160
1250	27.9333	1696	26.5446	1698	25.9827	1700	25.6237	1702	2250
1300	28.1029	1638	26.7144	1641	26.1527	1644	25.7939	1646	2340
1350	28.2667	1585	26.8785	1587	26.3171	1589	25.9585	1591	2430
1400	28.4252	1536	27.0372	1538	26.4760	1539	26.1176	1540	2520
1450	28.5788	1488	27.1910	1489	26.6299	1491	26.2716	1493	2610
1500	28.7276	1445	27.3399	1446	26.7790	1447	26.4209	1450	2700
1550	28.8721	1404	27.4845	1405	26.9237	1407	26.5659	1408	2790
1600	29.0125	1364	27.6250	1366	27.0644	1367	26.7067	1367	2880
1650	29.1489	1330	27.7616	1330	27.2011	1331	26.8434	1332	2970
1700	29.2819	1294	27.8946	1295	27.3342	1296	26.9766	1297	3060
1750	29.4113	1262	28.0241	1264	27.4638	1264	27.1063	1265	3150
1800	29.5375	1233	28.1505	1233	27.5902	1234	27.2328	1235	3240
1850	29.6608	1202	28.2738	1203	27.7136	1203	27.3563	1204	3330
1900	29.7810	1175	28.3941	1175	27.8339	1176	27.4767	1177	3420
1950	29.8985	1148	28.5116	1149	27.9515	1149	27.5944	1150	3510
2000	30.0133	1124	28.6265	1125	28.0664	1125	27.7094	1125	3600
2050	30.1257	1101	28.7390	1100	28.1789	1101	27.8219	1101	3690
2100	30.2358	1077	28.8490	1078	28.2890	1079	27.9320	1079	3780
2150	30.3435	1056	28.9568	1057	28.3969	1056	28.0399	1057	3870
2200	30.4491	1035	29.0625	1035	28.5025	1036	28.1456	1036	3960
2250	30.5526	1015	29.1660	1015	28.6061	1016	28.2492	1016	4050
2300	30.6541		29.2675		28.7077		28.3508		4140

Table 9.22/2 Entropy of Molecular Oxygen S/R

T °K.	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
2300	30.6541		29.2675		28.7077		28.3508		4140
		997		998		997		998	
2350	30.7538		29.3673		28.8074		28.4506		4230
		978		978		979		979	
2400	30.8516		29.4651		28.9053		28.5485		4320
		961		962		962		962	
2450	30.9477		29.5613		29.0015		28.6447		4410
		945		945		945		946	
2500	31.0422		29.6558		29.0960		28.7393		4500
		929		928		929		929	
2550	31.1351		29.7486		29.1889		28.8322		4590
		912		913		913		913	
2600	31.2263		29.8399		29.2802		28.9235		4680
		898		898		898		898	
2650	31.3161		29.9297		29.3700		29.0133		4770
		884		884		885		885	
2700	31.4045		30.0181		29.4585		29.1018		4860
		869		869		869		869	
2750	31.4914		30.1050		29.5454		29.1887		4950
		856		857		856		857	
2800	31.5770		30.1907		29.6310		29.2744		5040
		844		844		844		844	
2850	31.6614		30.2751		29.7154		29.3588		5130
		830		830		831		831	
2900	31.7444		30.3581		29.7985		29.4419		5220
		819		819		820		820	
2950	31.8263		30.4400		29.8805		29.5239		5310
		807		807		807		808	
3000	31.9070		30.5207		29.9612		29.6047		5400

Table 9.22 Enthalpy and Entropy of Oxygen

The Property Tabulated

The enthalpy and entropy of oxygen are tabulated in the dimensionless forms $(H - E_0^o)/RT_0$ and S/R as functions of temperature in ^oK and ^oR and of pressure in atmospheres. T_0 is the temperature of the ice point, 273.16 ^oK, and E_0^o is the enthalpy of the ideal gas at 0 ^oK.

The values tabulated were obtained by combining values for the ideal gas from Table 9.10 of this series with differences between the real and the ideal gas based on thermodynamic formulas and the virial coefficients used for Table 9.20 of this series.

The effect of dissociation is not included in this table, but its magnitude may be estimated using formulas given in reference 1. Graphs are included with this table showing the general magnitude of the effect of dissociation. If other constituents containing oxygen are present, the effects are more complicated.

Reliability of the Tables

The accuracy of the tabulated values varies with temperature and pressure. Disregarding the neglected effect of dissociation at the elevated temperatures, the error in the difference between real and ideal properties is thought to be somewhat less than 5% in the range of moderate pressure, but may be as great as 10% at the highest pressure.

Interpolation

Linear interpolation between successive tabulated temperatures at the same pressure is in general adequate for both entropy and enthalpy. Linear interpolation in the pressure direction is similarly valid in the enthalpy table. Linear interpolation is also in general adequate in the entropy table, provided the independent variable is the logarithm of the pressure rather than the pressure itself. The entries have, however, been spaced to permit Lagrangian interpolation directly in pressure.

Conversion Factors

The functions in this table have been expressed in dimensionless form. In order that they may be easily converted to any system of units, conversion factors are listed for the frequently used units.

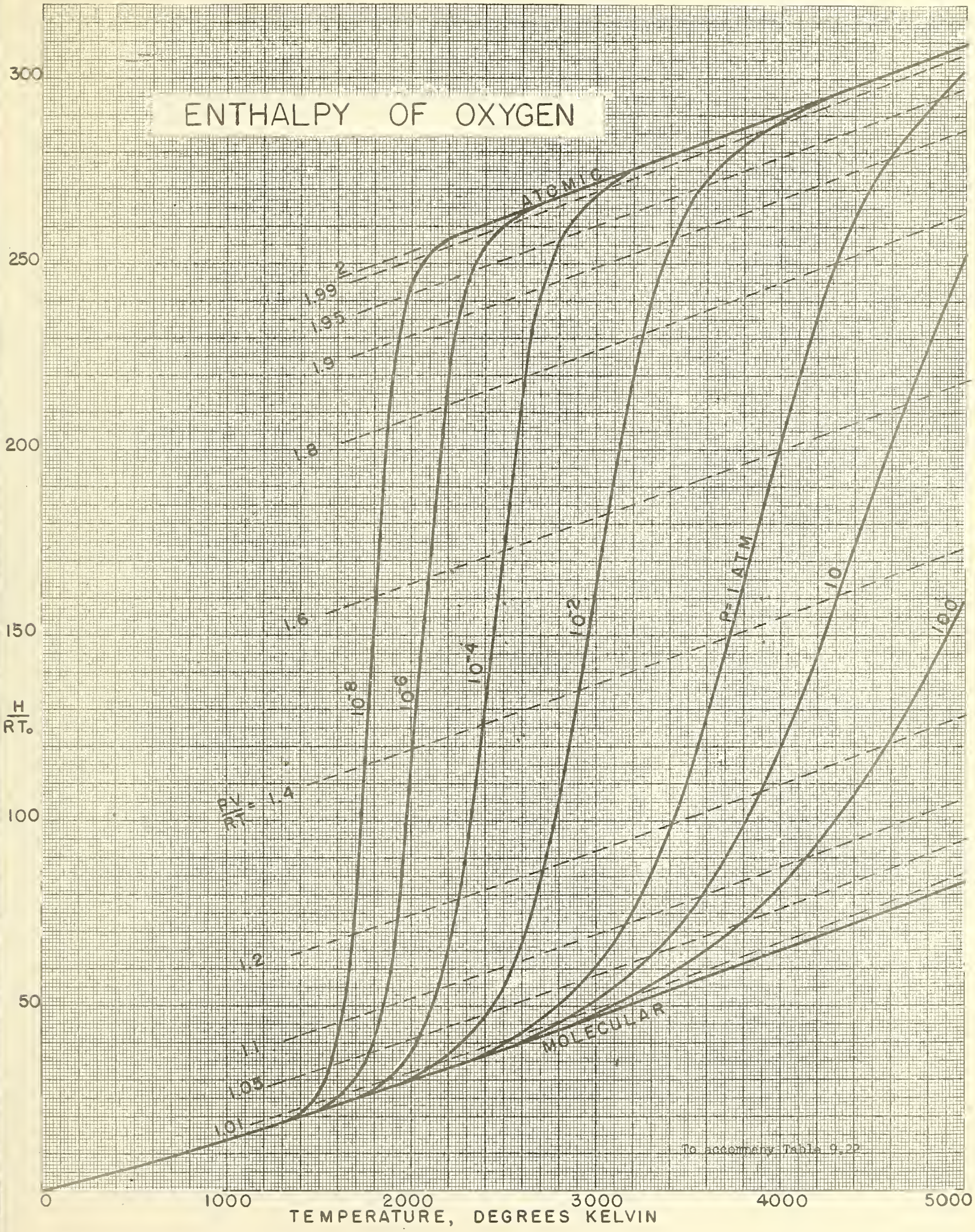
Conversion Factors

To convert tabulated value of	To Enthalpy with the Dimensions Indicated Below	Multiply by
$(H - E_0^o)/RT_0$	cal mole^{-1}	542.821
	cal g^{-1}	19.3754
	joules g^{-1}	81.0669
	Btu (lb mole)$^{-1}$	976.437
	Btu lb^{-1}	34.8528

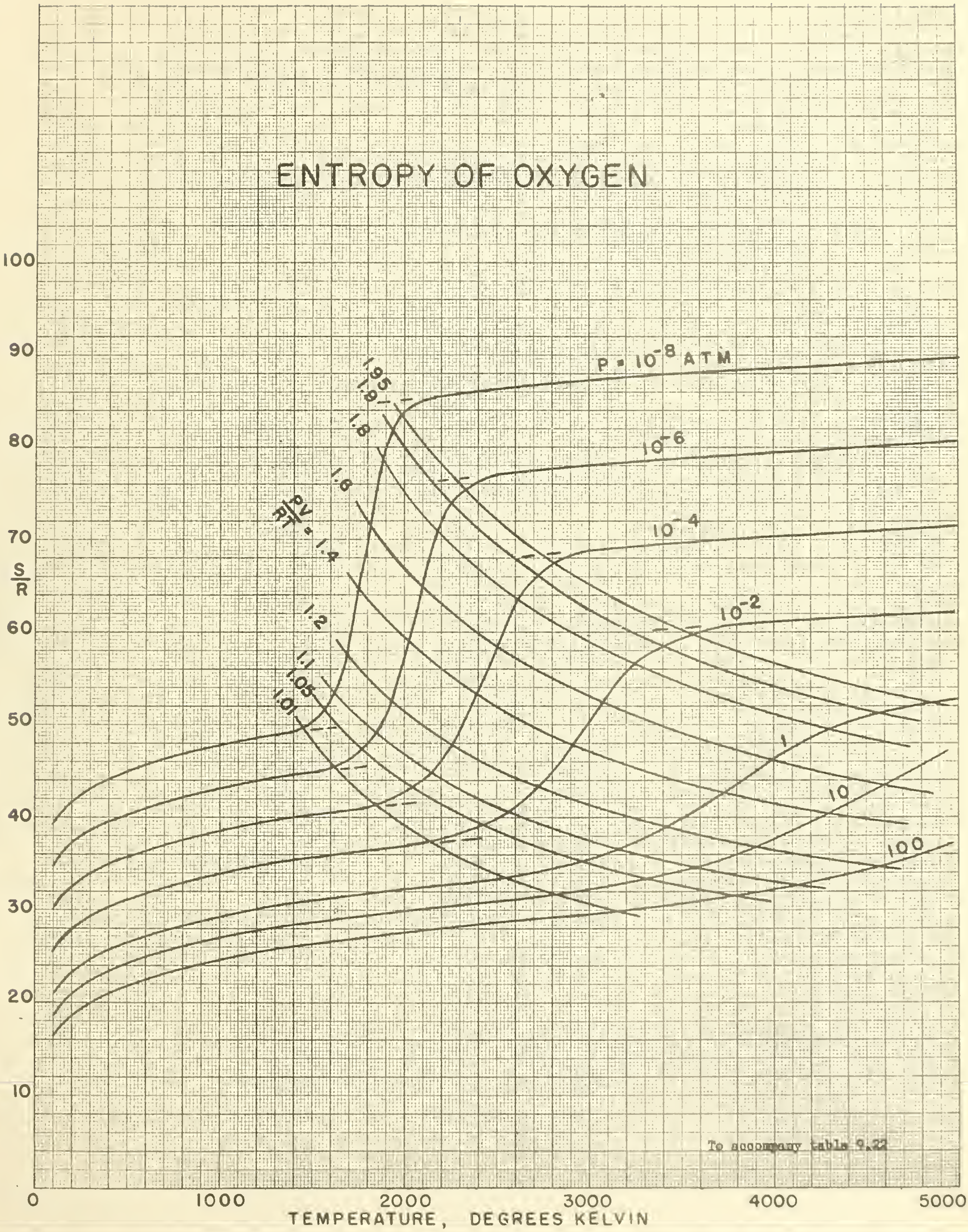
To convert tabulated value of	To the Dimensions Indicated Below	Multiply by
S/R	cal mole^{-1} $^oK^{-1}$ (or $^oC^{-1}$)	1.98719
	cal g^{-1} $^oK^{-1}$ (or $^oC^{-1}$)	0.0620996
	joules g^{-1} $^oK^{-1}$ (or $^oC^{-1}$)	0.259825
	Btu (lb mole)$^{-1}$ $^oR^{-1}$ (or $^oF^{-1}$)	1.98588
	Btu lb^{-1} $^oR^{-1}$ (or $^oF^{-1}$)	0.0620587

REFERENCE

[1] H. W. Woolley, The Effect of Dissociation on the Thermodynamic Properties of Pure Diatomic Gases, Report No. 1884, National Bureau of Standards, October 15, 1952.



ENTHALPY OF OXYGEN
ATOMIC
MOLECULAR
$\frac{H}{RT_0}$
$\frac{PV}{RT} = 1.4$
2
1.99
1.95
1.9
1.8
1.6
1.2
1.1
1.05
1.01
10^{-8}
10^{-6}
10^{-4}
10^{-2}
P = 1 ATM
10
100
0
50
100
150
200
250
300
1000
2000
3000
4000
5000
TEMPERATURE, DEGREES KELVIN
To accompany Table 9.22


ENTROPY OF OXYGEN
P = 10^-8 ATM
10^-6
10^-4
10^-2
1
10
100
PV/RT = 1.4
1.95
1.9
1.8
1.6
1.2
1.1
1.05
1.01
S/R
TEMPERATURE, DEGREES KELVIN
To accompany table 9.22

U. S. Department of Commerce National Bureau of Standards

The NBS - NACA Tables of Thermal Properties of Gases

Table 9.24 Specific Heat of Molecular Oxygen

Cp/R

by

Harold W. Woolley

June 1953

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	.01 atm		.1 atm		.4 atm		.7 atm		1 atm		T °R
100	3.5024	-3	3.5117	-27	3.5459	-126					180
110	3.5021	-2	3.5090	-17	3.5333	-74	3.5597	-145			198
120	3.5019	-2	3.5073	-13	3.5259	-52	3.5452	-94	3.566	-15	216
130	3.5017	-0	3.5060	-8	3.5207	-34	3.5358	-63	3.5513	-94	234
140	3.5017	-1	3.5052	-6	3.5173	-28	3.5295	-50	3.5419	-72	252
150	3.5016	+2	3.5046	-3	3.5145	-19	3.5245	-34	3.5347	-52	270
160	3.5018	1	3.5043	-2	3.5126	-14	3.5211	-27	3.5295	-39	288
170	3.5019	3	3.5041	-1	3.5112	-10	3.5184	-20	3.5256	-30	306
180	3.5022	5	3.5040	+3	3.5102	-6	3.5164	-13	3.5226	-21	324
190	3.5027	7	3.5043	5	3.5096	-1	3.5151	-8	3.5205	-15	342
200	3.5034	9	3.5048	8	3.5095	+3	3.5143	-4	3.5190	-8	360
210	3.5043	14	3.5056	12	3.5098	8	3.5139	+4	3.5182	-1	378
220	3.5057	17	3.5068	16	3.5106	11	3.5143	8	3.5181	+4	396
230	3.5074	22	3.5084	21	3.5117		3.5151		3.5185	11	414
240	3.5096	27	3.5105	26					3.5196	18	432
250	3.5123	33	3.5131	32					3.5214	24	450
260	3.5156	38	3.5163	38					3.5238	31	468
270	3.5194	45	3.5201	44					3.5269	38	486
280	3.5239	50	3.5245	49					3.5307	45	504
290	3.5289	56	3.5294	56					3.5352	51	522
300	3.5345	63	3.5350	63					3.5403	59	540
310	3.5408	69	3.5413	68					3.5462	65	558
320	3.5477	75	3.5481	75					3.5527	72	576
330	3.5552	79	3.5556	79					3.5599	76	594
340	3.5631	86	3.5635	86					3.5675	84	612
350	3.5717	90	3.5721	90					3.5759	87	630
360	3.5807	95	3.5811	95					3.5846	93	648
370	3.5902	100	3.5906	99					3.5939	97	666
380	3.6002	103	3.6005	103					3.6036	101	684
390	3.6105	107	3.6108	107					3.6137	106	702
400	3.6212	110	3.6215	110					3.6243	108	720
410	3.6322	113	3.6325	113					3.6351	111	738
420	3.6435	115	3.6438	115					3.6462	114	756
430	3.6550	118	3.6553	117					3.6576	117	774
440	3.6668	119	3.6670	119					3.6693	118	792
450	3.6787		3.6789						3.6811		810

Table 9. 24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure . 01 atm		. 1 atm		1 atm		10 atm		T °R
450	3. 6787	120	3. 6789	120	3. 6811	118	3. 7022	108	810
460	3. 6907	122	3. 6909	122	3. 6929	121	3. 7130	112	828
470	3. 7029	122	3. 7031	122	3. 7050	121	3. 7242	112	846
480	3. 7151	123	3. 7153	123	3. 7171	122	3. 7354	114	864
490	3. 7274	122	2. 7276	122	3. 7293	122	3. 7468	114	882
500	3. 7396	124	3. 7398	124	3. 7415	123	3. 7582	115	900
510	3. 7520	123	3. 7522	123	3. 7538	122	3. 7697	115	918
520	3. 7643	122	3. 7645	122	3. 7660	121	3. 7812	115	936
530	3. 7765	122	3. 7767	122	3. 7781	122	3. 7927	116	954
540	3. 7887	121	3. 7889	121	3. 7903	120	3. 8043	114	972
550	3. 8008	121	3. 8010	120	3. 8023	120	3. 8157	115	990
560	3. 8129	119	3. 8130	119	3. 8143	119	3. 8272	114	1008
570	3. 8248	118	3. 8249	118	3. 8262	117	3. 8386	113	1026
580	3. 8366	117	3. 8367	117	3. 8379	117	3. 8499	112	1044
590	3. 8483	116	3. 8484	116	3. 8496	115	3. 8611	111	1062
600	3. 8599	114	3. 8600	114	3. 8611	114	3. 8722	109	1080
610	3. 8713	113	3. 8714	113	3. 8725	112	3. 8831	109	1098
620	3. 8826	111	3. 8827	111	3. 8837	111	3. 8940	107	1116
630	3. 8937	110	3. 8938	110	3. 8948	110	3. 9047	106	1134
640	3. 9047	108	3. 9048	108	3 9058	107	3. 9153	104	1152
650	3. 9155	107	3. 9156	107	3. 9165	107	3. 9257	104	1170
660	3. 9262	105	3. 9263	105	3. 9272	105	3. 9361	102	1188
670	3. 9367	103	3. 9368	103	3. 9377	102	3. 9463	100	1206
680	3. 9470	101	3. 9471	101	3. 9479	101	3. 9563	98	1224
690	3. 9571	101	3. 9572	101	3. 9580	101	3. 9661	98	1242
700	3. 9672	98	3. 9673	98	3. 9681	97	3 9759	95	1260
710	3. 9770	96	3. 9771	95	3. 9778	96	3. 9854	94	1278
720	3. 9866	95	3. 9866	96	3. 9874	95	3. 9948	92	1296
730	3. 9961	93	3. 9962	93	3. 9969	93	4. 0040	91	1314
740	4. 0054	91	4. 0055	91	4. 0062	90	4. 0131	88	1332
750	4. 0145	90	4. 0146	90	4. 0152	90	4. 0219	88	1350
760	4. 0235	88	4. 0236	87	4. 0242	88	4. 0307	86	1368
770	4. 0323	86	4. 0323	87	4. 0330	86	4. 0393	84	1386
780	4. 0409	85	4. 0410	85	4 0416	85	4. 0477	83	1404
790	4. 0494	83	4. 0495	83	4. 0501	82	4. 0560	81	1422
800	4. 0577		4. 0578		4. 0583		4. 0641		1440

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure: .01 atm		.1 atm		1 atm		10 atm		T °R
800	4.0577	393	4.0578	393	4.0583	392	4.0641	385	1440
850	4.0970	357	4.0971	356	4.0975	357	4.1026	350	1530
900	4.1327	325	4.1327	325	4.1332	324	4.1376	320	1620
950	4.1652	296	4.1652	296	4.1656	296	4.1696	291	1710
1000	4.1948	271	4.1948	271	4.1952	270	4.1987	267	1800
1050	4.2219	250	4.2219	250	4.2222	250	4.2254	246	1890
1100	4.2469	229	4.2469	229	4.2472	229	4.2500	226	1980
1150	4.2698	214	4.2698	214	4.2701	214	4.2726	211	2070
1200	4.2912	200	4.2912	200	4.2915	199	4.2937	198	2160
1250	4.3112	188	4.3112	188	4.3114	188	4.3135	186	2250
1300	4.3300	179	4.3300	179	4.3302	179	4.3321	177	2340
1350	4.3479	172	4.3479	172	4.3481	172	4.3498	171	2430
1400	4.3651	164	4.3651	164	4.3653	164	4.3669	162	2520
1450	4.3815	160	4.3815	160	4.3817	159	4.3831	159	2610
1500	4.3975	155	4.3975	155	4.3976	155	4.3990	154	2700
1550	4.4130	152	4.4130	152	4.4131	152	4.4144	151	2790
1600	4.4282	149	4.4282	149	4.4283	149	4.4295	148	2880
1650	4.4431	147	4.4431	147	4.4432	147	4.4443	146	2970
1700	4.4578	146	4.4578	146	4.4579	146	4.4589	145	3060
1750	4.4724	144	4.4724	144	4.4725	144	4.4734	144	3150
1800	4.4868	143	4.4868	143	4.4869	143	4.4878	142	3240
1850	4.5011	142	4.5011	142	4.5012	142	4.5020	141	3330
1900	4.5153	142	4.5153	142	4.5154	142	4.5161	142	3420
1950	4.5295	141	4.5295	141	4.5296	141	4.5303	140	3510
2000	4.5436	140	4.5436	140	4.5437	140	4.5443	140	3600
2050	4.5576	139	4.5576	139	4.5577	139	4.5583	138	3690
2100	4.5715	139	4.5715	139	4.5716	139	4.5721	139	3780
2150	4.5854	139	4.5854	139	4.5855	138	4.5860	139	3870
2200	4.5993	137	4.5993	137	4.5993	137	4.5999	136	3960
2250	4 6130	137	4.6130	137	4.6130	138	4.6135	137	4050
2300	4.6267		4.6267		4.6268		4.6272		4140

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure .01 atm		.1 atm		1 atm		10 atm		T °R
2300	4.6267	137	4.6267	137	4.6268	136	4.6272	137	4140
2350	4.6404	136	4.6404	136	4.6404	136	4.6409	135	4230
2400	4.6540	134	4.6540	134	4.6540	134	4.6544	134	4320
2450	4.6674	134	4.6674	134	4.6674	134	4.6678	134	4410
2500	4.6808	132	4.6808	132	4.6808	132	4.6812	132	4500
2550	4.6940	131	4.6940	131	4.6940	131	4.6944	130	4590
2600	4.7071	129	4.7071	129	4.7071	129	4.7074	129	4680
2650	4.7200	128	4.7200	128	4.7200	128	4.7203	128	4770
2700	4.7328	126	4.7328	126	4.7328	126	4.7331	126	4860
2750	4.7454	125	4.7454	125	4.7454	125	4.7457	125	4950
2800	4.7579	124	4.7579	124	4.7579	124	4.7582	124	5040
2850	4.7703	121	4.7703	121	4.7703	121	4.7706	120	5130
2900	4.7824	120	4.7824	120	4.7824	120	4.7826	120	5220
2950	4.7944	118	4.7944	118	4.7944	118	4.7946	118	5310
3000	4.8062		4.8062		4.8062		4.8064		5400

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure: 1 atm		4 atm		7 atm		10 atm		T °R
120	3.566	-15							216
130	3.5513	-94							234
140	3.5419	-72	3.684	-38					252
150	3.5347	-52	3.6461	-255	3.781	-56	3.951	-104	270
160	3.5295	-39	3.6206	-188	3.7252	-389	3.847	-67	288
170	3.5256	-30	3.6018	-143	3.6863	-284	3.780	-46	306
180	3.5226	-21	3.5875	-109	3.6579	-216	3.7343	-342	324
190	3.5205	-15	3.5766	-85	3.6363	-167	3.7001	-262	342
200	3.5190	-8	3.5681	-68	3.6196	-132	3.6739	-205	360
210	3.6182	-1	3.5613	-48	3.6064	-102	3.6534	-160	378
220	3.5181	+ 4	3.5565	-39	3.5962	-80	3.6374	-128	396
230	3.5185	11	3.5526	-22	3.5882	-61	3.6246	-100	414
240	3.5196	18	3.5504	-16	3.5821	-43	3.6146	-75	432
250	3.5214	24	3.5488	+ 3	3.5778	-27	3.6071	-55	450
260	3.5238	31	3.5491	10	3.5751	-15	3.6016	-39	468
270	3.5269	38	3.5501	19	3.5736	-1	3.5977	-22	486
280	3.5307	45	3.5520	27	3.5735	10	3.5955	-8	504
290	3.5352	51	3.5547	37	3.5745	21	3.5947	+ 4	522
300	3.5403	59	3.5584	45	3.5766	31	3.5951	17	540
310	3 5462	65	3.5629	52	3.5797	41	3.5968	28	558
320	3.5527	72	3.5681	61	3.5838	49	3.5996	39	576
330	3.5599	76	3.5742	68	3 5887	58	3.6035	47	594
340	3.5675	84	3.5810	74	3.5945	65	3.6082	56	612
350	3.5759	87	3.5884	80	3.6010	72	3.6138	63	630
360	3.5846	93	3.5964	85	3.6082	78	3.6201	70	648
370	3.5939	97	3.6049	91	3.6160	84	3.6271	78	666
380	3.6036	101	3.6140	95	3.6244	89	3.6349	83	684
390	3.6137	106	3.6235	100	3.6333	94	3.6432	88	702
400	3.6243	108	3.6335	103	3.6427	99	3.6520	94	720
410	3.6351	111	3.6438	107	3.6526	102	3.6614	96	738
420	3.6462	114	3.6545	109	3.6628	104	3.6710	101	756
430	3.6576	117	3.6654	113	3.6732	109	3.6811	105	774
440	3.6693	118	3.6767	114	3.6841	110	3.6916	106	792
450	3.6811		3.6881		3.6951		3.7022		810

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
150	3.951	-104							270
160	3.847	-67							288
170	3.780	-46	5.7	-7					306
180	3.7343	-342	5.03	-38					324
190	3.7001	-262	4.65	-23	6.5	-8			342
200	3.6739	-205	4.415	-162	5.66	-50	7.6	-11	360
210	3.6534	-160	4.253	-116	5.16	-33	6.48	-72	378
220	3.6374	-128	4.137	-88	4.831	-237	5.76	-49	396
230	3.6246	-100	4.049	-67	4.594	-168	5.27	-32	414
240	3.6146	-75	3.982	-52	4.426	-125	4.95	-24	432
250	3.6071	-55	3.9296	-422	4.301	-97	4.710	-173	450
260	3.6016	-39	3.8874	-339	4.204	-75	4.537	-130	468
270	3.5977	-22	3.8535	-272	4.129	-60	4.407	-100	486
280	3.5955	-8	3.8263	-222	4.069	-49	4.307	-78	504
290	3.5947	+4	3.8041	-179	4.020	-39	4.229	-64	522
300	3.5951	17	3.7862	-141	3.981	-32	4.165	-52	540
310	3.5968	28	3.7721	-111	3.949	-26	4.113	-41	558
320	3.5996	39	3.7610	-84	3.923	-22	4 072	-34	576
330	3.6035	47	3.7526	-60	3.901	-17	4.038	-29	594
340	3.6082	56	3 7466	-41	3.884	-15	4.009	-23	612
350	3.6138	63	3.7425	-22	3.869	-11	3.986	-19	630
360	3.6201	70	3.7403	-7	3.858	-8	3.967	-15	648
370	3.6271	78	3.7396	+8	3.850	-6	3.952	-13	666
380	3.6349	83	3 7404	18	3.844	-5	3.939	-10	684
390	3.6432	88	3.7422	31	3.839	-3	3.929	-8	702
400	3.6520	94	3.7453	40	3.836	-1	3.921	-5	720
410	3.6614	96	3.7493	47	3.835	0	3.916	-5	738
420	3.6710	101	3.7540	56	3.835	+2	3.911	-2	756
430	3.6811	105	3.7596	64	3.837	2	3.909	-1	774
440	3.6916	106	3.7660	69	3.839	3	3.908	0	792
450	3.7022		3.7729		3.842		3.908		810

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
450	3.7022	108	3.7729	73	3.8420	38	3.908	0	810
460	3.7130	112	3.7802	79	3.8458	47	3.908	2	828
470	3.7242	112	3.7881	81	3.8505	53	3.910	3	846
480	3.7354	114	3.7962	86	3.8558	57	3.913	3	864
490	3.7468	114	3.8048	86	3.8615	62	3.916	4	882
500	3.7582	115	3.8134	91	3.8677	67	3.920	4	900
510	3.7697	115	3.8225	93	3.8744	70	3.924	5	918
520	3.7812	115	3.8318	93	3.8814	72	3.929	5	936
530	3.7927	116	3.8411	96	3.8886	76	3.934	6	954
540	3.8043	114	3.8507	95	3.8962	76	3.940	6	972
550	3.8157	115	3.8602	97	3.9038	80	3.946	6	990
560	3.8272	114	3.8699	97	3.9118	80	3.952	8	1008
570	3.8386	113	3.8796	96	3.9198	82	3.960	7	1026
580	3.8499	112	3.8892	97	3.9280	82	3.967	6	1044
590	3.8611	111	3.8989	98	3.9362	83	3.973	7	1062
600	3.8722	109	3.9087	96	3.9445	83	3.980	6	1080
610	3.8831	109	3.9183	95	3.9528	83	3.986	8	1098
620	3.8940	107	3.9278	96	3.9611	83	3.994	7	1116
630	3.9047	106	3 9374	94	3.9694	84	4.001	8	1134
640	3.9153	104	3.9468	94	3.9778	83	4.009	7	1152
650	3.9257	104	3.9562	93	3.9861	83	4.016	8	1170
660	3.9361	102	3.9655	92	3.9944	82	4.024	7	1188
670	3.9463	100	3.9747	90	4.0026	81	4.031	7	1206
680	3.9563	98	3.9837	89	4.0107	80	4.038	7	1224
690	3.9661	98	3.9926	90	4.0187	79	4.045	7	1242
700	3.9759	95	4.0016	87	4.0266	78	4.052	7	1260
710	3.9854	94	4.0103	85	4.0344	78	4.059	7	1278
720	3.9948	92	4.0188	85	4.0422	78	4.066	7	1296
730	4.0040	91	4.0273	84	4.0500	76	4.073	7	1314
740	4.0131	88	4.0357	82	4.0576	75	4.080	6	1332
750	4.0219	88	4.0439	81	4.0651	75	4.086	8	1350
760	4.0307	86	4.0520	80	4.0726	74	4.094	7	1368
770	4.0393	84	4.0600	77	4.0800	72	4.101	6	1386
780	4.0477	83	4.0677	78	4.0872	71	4.107	7	1404
790	4.0560	81	4.0755	75	4.0943	74	4.114	6	1422
800	4.0641		4.0830		4.1017		4.120		1440

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
800	4.0641	385	4.0830	360	4.1017	337	4.120	31	1440
850	4.1026	350	4.1190	331	4.1354	310	4.151	29	1530
900	4.1376	320	4.1521	302	4.1664	286	4.180	27	1620
950	4.1696	291	4.1823	278	4.1950	263	4.207	25	1710
1000	4.1987	267	4.2101	254	4.2213	242	4.232	23	1800
1050	4.2254	246	4.2355	236	4.2455	226	4.255	22	1890
1100	4.2500	226	4.2591	217	4.2681	208	4.277	20	1980
1150	4.2726	211	4.2808	204	4.2889	196	4.297	19	2070
1200	4.2937	198	4.3012	190	4.3085	185	4.316	18	2160
1250	4.3135	186	4.3202	180	4.3270	172	4.334	16	2250
1300	4.3321	177	4.3382	173	4.3442	166	4.350	16	2340
1350	4.3498	171	4.3555	166	4.3608	163	4.366	16	2430
1400	4.3669	162	4.3721	158	4.3771	154	4.382	15	2520
1450	4.3831	159	4.3879	155	4.3925	151	4.397	15	2610
1500	4.3990	154	4.4034	150	4.4076	148	4.412	14	2700
1550	4.4144	151	4.4184	148	4.4224	145	4.426	14	2790
1600	4.4295	148	4.4332	145	4.4369	142	4.440	14	2880
1650	4.4443	146	4.4477	144	4.4511	141	4.454	14	2970
1700	4.4589	145	4.4621	143	4.4652	142	4.468	14	3060
1750	4.4734	144	4.4764	141	4.4794	139	4.482	14	3150
1800	4.4878	142	4.4905	142	4.4933	138	4.496	14	3240
1850	4.5020	141	4.5047	138	4.5071	138	4.510	13	3330
1900	4.5161	142	4.5185	140	4.5209	138	4.523	14	3420
1950	4.5303	140	4.5325	139	4.5347	138	4.537	14	3510
2000	4.5443	140	4.5464	138	4.5485	137	4.551	13	3600
2050	4.5583	138	4.5602	137	4.5622	136	4.564	14	3690
2100	4.5721	139	4.5739	139	4.5758	138	4.578	13	3780
2150	4.5860	139	4.5878	138	4.5896	136	4.591	14	3870
2200	4.5999	136	4.6016	135	4.6032	134	4.605	13	3960
2250	4.6135	137	4.6151	136	4.6166	135	4.618	13	4050
2300	4.6272		4.6287		4.6301		4.631		4140

Table 9.24 Specific Heat of Molecular Oxygen C_p/R

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
2300	4.6272	137	4.6287	136	4.6301	135	4.631	14	4140
2350	4.6409	135	4.6423	135	4.6436	134	4.645	13	4230
2400	4.6544	134	4.6558	133	4.6570	132	4.658	13	4320
2450	4.6678	134	4.6691	133	4.6702	133	4.671	14	4410
2500	4.6812	132	4.6824	131	4.6835	130	4.685	13	4500
2550	4.6944	130	4.6955	130	4.6965	130	4.698	12	4590
2600	4.7074	129	4.7085	128	4.7095	127	4.710	13	4680
2650	4.7203	128	4.7213	128	4.7222	127	4.723	13	4770
2700	4.7331	126	4.7341	125	4.7349	125	4.736	12	4860
2750	4.7457	125	4.7466	124	4.7474	124	4.748	13	4950
2800	4.7582	124	4.7590	124	4.7598	123	4.761	12	5040
2850	4.7706	120	4.7714	120	4.7721	120	4.773	12	5130
2900	4.7826	120	4.7834	120	4.7841	119	4.785	12	5220
2950	4.7946	118	4.7954	118	4.7960	117	4.797	11	5310
3000	4.8064		4.8072		4.8077		4.808		5400

Table 9.24 Specific Heat at Constant Pressure of Oxygen

The Property Tabulated

The specific heat of oxygen at constant pressure is tabulated in the dimensionless form Cp/R as a function of temperature in $^{\circ}$K and $^{\circ}$R, and of pressure in atmospheres. Values for .4, .7, 4 and 7 atmospheres have been omitted for temperatures at which the values may be obtained by linear interpolation between lower and higher pressures.

The specific heat values were obtained by combining the ideal gas specific heat values from Table 9.10 of this series with differences between real and ideal based on thermodynamic formulas and the virial coefficients used for Table 9.20 of this series.

The effect of dissociation is not included in this table but its magnitude may be estimated with the formulas given in reference [5].

Reliability of the Tables

The accuracy of the tabulated values varies with temperature and pressure. Disregarding the considerable deviation due to dissociation at elevated temperature and low and moderate pressure, the error in $Cp - C_p^o$ is thought to be somewhat less than 5% in the range of moderate pressure but may be as great as 10% at the highest pressure. Figure 1 gives a comparison between experimental values for the specific heat [1 - 4] and this table. Figure 2 shows the data of Workman [6] for the dependence of specific heat upon pressure at 26°C and 60°C, with the indications of the present correlation shown as curves for comparison.

Interpolation

The error produced by linear interpolation varies throughout the table but does not in general exceed one eighth of the second difference, so that for most of the table linear interpolation is adequate.

Conversion Factors

The function in the table has been expressed in dimensionless form. In order that it may be easily converted to any system of units, conversion factors are listed for the frequently used units. For other conversion factors see Table 1.30 of this series.

Conversion Factors

To convert tabulated value of	To the dimensions indicated below	Multiply by
Cp/R	cal mole^{-1} $^{o}K^{-1}$ (or $^{o}C^{-1}$)	1.98719
	cal g^{-1} $^{o}K^{-1}$ (or $^{o}C^{-1}$)	0.0620996
	joules g^{-1} $^{o}K^{-1}$ (or $^{o}C^{-1}$)	0.259825
	Btu (lb mole)$^{-1}$ $^{o}R^{-1}$ (or $^{o}F^{-1}$)	1.98588
	Btu lb^{-1} $^{o}R^{-1}$ (or $^{o}F^{-1}$)	0.0620587

REFERENCES

[1] A. Eucken and K. v. Lüde, Die spezifische Wärme der Gase bei mittleren und hohen Temperaturen. I. Die spezifische Wärme der Gase: Luft, Stickstoff, Sauerstoff, Kohlenoxyd, Kohlensäure, Stickoxydul, und Methan zwischen 0° und 220°C, Z. physik. Chem. B5, 413 (1929).

[2] P. S. H. Henry, The specific heat of Air, Oxygen, Nitrogen from 20° to 370°C, Proc. Roy. Soc. (London) A. 133, 492 (1931).

[3] W. G. Shilling and J. R. Partington, Measurements of the velocity of sound in air, nitrogen and oxygen with special reference to the temperature coefficients of the molecular heats, Phil. Mag., 6, 920 (1928).

[4] P. F. Wacker, R. K. Cheney and R. B. Scott, Heat capacities of gaseous oxygen, isobutane and 1-butane from -30° to 90°, J. Research, Nat. Bureau of Standards, 38, 651 (1947). R.P. 1804.

[5] H. W. Woolley, The effect of dissociation on the thermodynamic properties of pure diatomic gases, Report No. 1884, National Bureau of Standards, Oct. 15, 1952.

[6] E. J. Workman, The variation of the specific heats (C_p) of oxygen, nitrogen and hydrogen with pressure, Phys. Rev., 37, 1345 (1931).

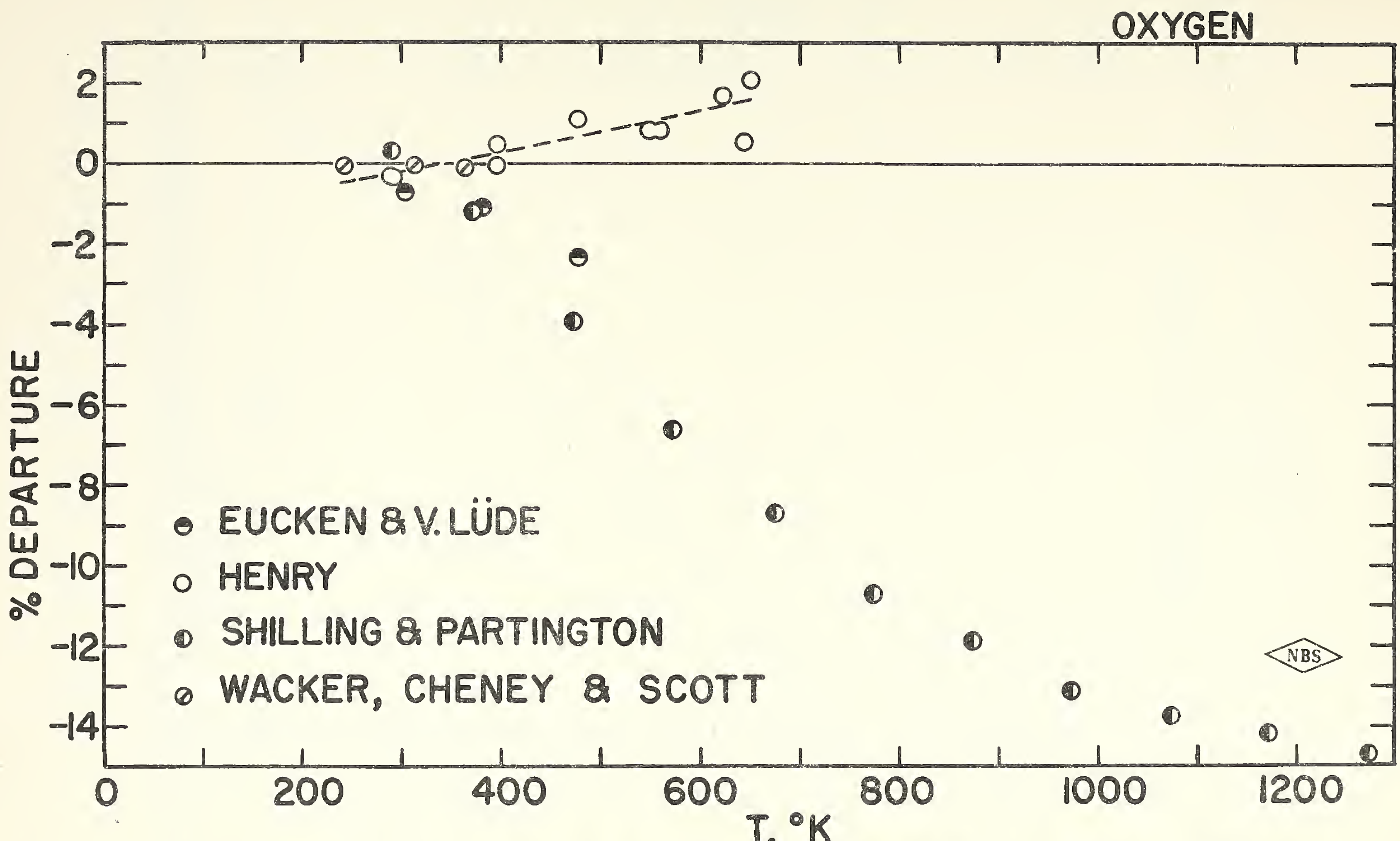


FIG. 1. DEPARTURE OF EXPERIMENTAL SPECIFIC HEAT FROM TABLE 9.24

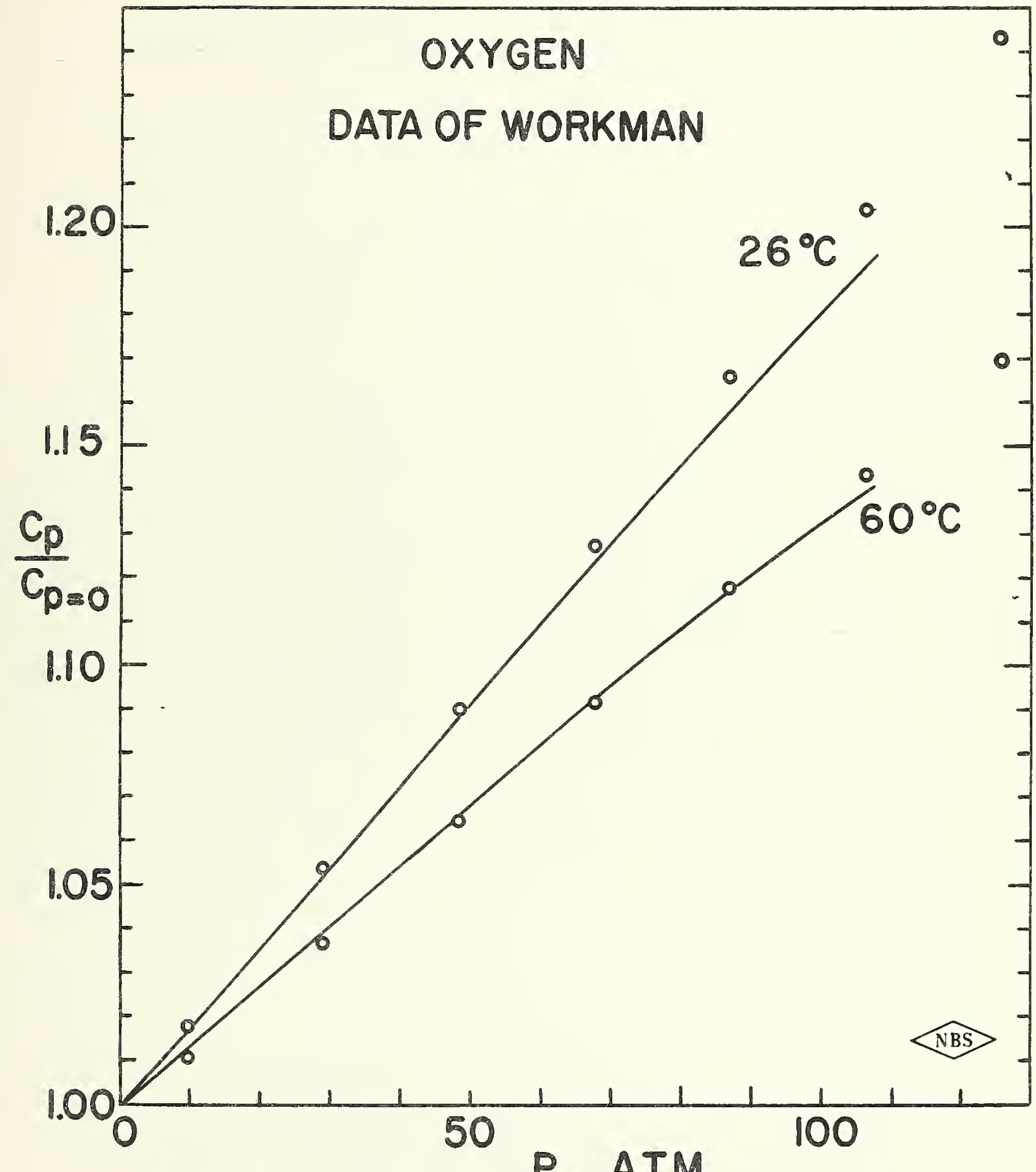


FIG. 2. DEPENDENCE OF SPECIFIC HEAT UPON PRESSURE

U. S. Department of Commerce National Bureau of Standards

NBS-NACA Tables of Thermal Properties of Gases

Table 9.26 Specific Heat Ratios of Molecular Oxygen

γ

by

Harold W. Woolley

June 1953

Table 9.26 Specific Heat Ratios of Molecular Oxygen γ

T °K	Pressure .01 atm	.1 atm	1 atm	4 atm	7 atm	10 atm	T °R
100	1.400	1.402					180
120	1.400	1.401	1.417 -6				216
140	1.400	1.401	1.411 -3	1.450 -15			252
160	1.400	1.401	1.408 -2	1.435 - 9	1.466 -18	1.500 -29	288
180	1.400	1.400	1.406	1.426 - 6	1.448 -12	1.471 -18	324
200	1.400	1.400	1.404	1.420	1.436 - 8	1.453 -12	360
220	1.399	1.400	1.403	1.415	1.428 - 6	1.441 - 9	396
240	1.399	1.399	1.402	1.412	1.422 - 5	1.432 - 7	432
260	1.398	1.398	1.400	1.408	1.417 - 5	1.425 - 5	468
280	1.396	1.396	1.398	1.405	1.412 - 4	1.420 - 6	504
300	1.395	1.395	1.396	1.402	1.408	1.414 - 5	540
320	1.393	1.393	1.394	1.399	1.404	1.409 - 4	576
340	1.390	1.390	1.392	1.396	1.400	1.405 - 5	612
360	1.388	1.388	1.389	1.392	1.396	1.400 - 4	648
380	1.385	1.385	1.386	1.389	1.392	1.396 - 5	684
400	1.382	1.382	1.382	1.385	1.388	1.391	720
420	1.378	1.378	1.379	1.382	1.384	1.387	756
440	1.375	1.375	1.376	1.378	1.380	1.383	792
460	1.372	1.372	1.372	1.374	1.376	1.378	828
480	1.368	1.368	1.369	1.371	1.373	1.374	864
500	1.365	1.365	1.366	1.367	1.369	1.371	900
520	1.362	1.362	1.362	1.364	1.365	1.367	936
540	1.359	1.359	1.359	1.360	1.362	1.363	972
560	1.356	1.355	1.356	1.357	1.358	1.360	1008
580	1.353	1.353	1.353	1.354	1.355	1.356	1044
600	1.350	1.350	1.350	1.351	1.352	1.353	1080
620	1.347	1.347	1.347	1.348	1.349	1.350	1116
640	1.344	1.344	1.344	1.345	1.346	1.347	1152
660	1.342	1.342	1.342	1.343	1.344	1.344	1188
680	1.339	1.339	1.340	1.340	1.341	1.342	1224
700	1.337	1.337	1.337	1.338	1.339	1.339	1260
720	1.335	1.335	1.335	1.336	1.336	1.337	1296
740	1.333	1.333	1.333	1.334	1.334	1.335	1332
760	1.331	1.331	1.331	1.332	1.332	1.333	1368
780	1.329	1.329	1.329	1.330	1.330	1.331	1404
800	1.327	1.327	1.327	1.328	1.328	1.329	1440

Table 9.26 Specific Heat Ratios of Molecular Oxygen γ

T °K	Pressure: .01 atm	.1 atm	1 atm	4 atm	7 atm	10 atm	T °R
800	1.327	1.327	1.327	1.328	1.328	1.329	1440
900	1.319	1.319	1.319	1.320	1.320	1.320	1620
1000	1.313	1.313	1.313	1.313	1.314	1.314	1800
1100	1.308	1.308	1.308	1.308	1.308	1.309	1980
1200	1.304	1.304	1.304	1.304	1.304	1.304	2160
1300	1.300	1.300	1.300	1.300	1.301	1.301	2340
1400	1.297	1.297	1.297	1.297	1.297	1.297	2520
1500	1.294	1.294	1.294	1.294	1.294	1.295	2700
1600	1.292	1.292	1.292	1.292	1.292	1.292	2880
1700	1.289	1.289	1.289	1.289	1.289	1.289	3060
1800	1.287	1.287	1.287	1.287	1.287	1.287	3240
1900	1.285	1.285	1.284	1.284	1.284	1.285	3420
2000	1.282	1.282	1.282	1.282	1.282	1.282	3600
2100	1.280	1.280	1.280	1.280	1.280	1.280	3780
2200	1.278	1.278	1.278	1.278	1.278	1.278	3960
2300	1.276	1.276	1.276	1.276	1.276	1.276	4140
2400	1.274	1.274	1.274	1.274	1.274	1.274	4320
2500	1.272	1.272	1.272	1.272	1.272	1.272	4500
2600	1.270	1.270	1.270	1.270	1.270	1.270	4680
2700	1.268	1.268	1.268	1.268	1.268	1.268	4860
2800	1.266	1.266	1.266	1.266	1.266	1.266	5040
2900	1.264	1.264	1.264	1.264	1.264	1.264	5220
3000	1.263	1.263	1.263	1.263	1.263	1.263	5400

Table 9. 26 Specific Heat Ratios of Molecular Oxygen γ

T °K	Pressure: 10 atm		40 atm		70 atm		100 atm		T °R
120									216
140									252
160	1.500	-29							288
180	1.471	-18	1.84	-16					324
200	1.453	-12	1.683	-81	2.08	-26			360
220	1.441	-9	1.602	-49	1.818	-124	2.12	-27	396
240	1.432	-7	1.553	-33	1.694	-71	1.85	-13	432
260	1.425	-5	1.520	-24	1.623	-46	1.721	-73	468
280	1.420	-6	1.496	-18	1.577	-35	1.648	-49	504
300	1.414	-5	1.478	-15	1.542	-24	1.599	-35	540
320	1.409	-4	1.463	-13	1.518	-23	1.564	-27	576
340	1.405	-5	1.450	-11	1.495	-17	1.537	-23	612
360	1.400	-4	1.439	-10	1.478	-15	1.514	-19	648
380	1.396	-5	1.429	-8	1.463	-13	1.495	-17	684
400	1.391		1.421	-8	1.450	-11	1.478	-14	720
420	1.387		1.413	-7	1.439	-10	1.464	-13	756
440	1.383		1.406	-7	1.429	-10	1.451	-12	792
460	1.378		1.399	-6	1.419	-8	1.439	-10	828
480	1.374		1.393	-6	1.411	-7	1.429	-9	864
500	1.371		1.387	-5	1.404	-7	1.420	-9	900
520	1.367		1.382	-5	1.397	-7	1.411	-8	936
540	1.363		1.377	-5	1.390	-6	1.403	-7	972
560	1.360		1.372	-4	1.384	-6	1.396	-7	1008
580	1.356		1.368	-5	1.378	-5	1.389	-6	1044
600	1.353		1.363		1.373	-4	1.383	-5	1080
620	1.350		1.360		1.369	-5	1.378	-5	1116
640	1.347		1.356		1.364	-4	1.373	-5	1152
660	1.344		1.352		1.360	-4	1.368	-5	1188
680	1.342		1.349		1.356	-3	1.363	-4	1224
700	1.339		1.346		1.353		1.359		1260
720	1.337		1.343		1.349		1.355		1296
740	1.335		1.341		1.346		1.352		1332
760	1.333		1.338		1.343		1.349		1368
780	1.331		1.336		1.340		1.345		1404
800	1.329		1.333		1.338		1.342		1440

Table 9.26 Specific Heat Ratios of Molecular Oxygen γ

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
800	1.329	-9	1.333	-9	1.338	-11	1.342	-12	1440
900	1.320	-6	1.324	-8	1.327	-8	1.330	-9	1620
1000	1.314	-5	1.316	-6	1.319	-7	1.321	-7	1800
1100	1.309	-5	1.310	-4	1.312	-5	1.314	-6	1980
1200	1.304	-3	1.306	-4	1.307	-4	1.308	-4	2160
1300	1.301		1.302		1.303		1.304		2340
1400	1.297		1.298		1.299		1.300		2520
1500	1.295		1.295		1.296		1.297		2700
1600	1.292		1.292		1.293		1.293		2880
1700	1.289		1.290		1.290		1.290		3060
1800	1.287		1.287		1.287		1.288		3240
1900	1.285		1.285		1.285		1.285		3420
2000	1.282		1.282		1.283		1.283		3600
2100	1.280		1.280		1.280		1.280		3780
2200	1.278		1.278		1.278		1.278		3960
2300	1.276		1.276		1.276		1.276		4140
2400	1.274		1.274		1.274		1.274		4320
2500	1.272		1.272		1.272		1.272		4500
2600	1.270		1.270		1.270		1.270		4680
2700	1.268		1.268		1.268		1.268		4860
2800	1.266		1.266		1.266		1.266		5040
2900	1.264		1.264		1.264		1.264		5220
3000	1.263		1.263		1.263		1.263		5400

Table 9.26 Specific Heat Ratio for Oxygen

The Property Tabulated

The specific heat ratio $\gamma = Cp/Cv$ of oxygen is tabulated as a function of temperature in degrees Kelvin and Rankine and of pressure in atmospheres. The effect of dissociation is not included in this table.

To obtain the values of γ for this table, valuesof Cp/R as given in Table 9.24 of this series were combined with

$$\frac{C_p - C_v}{R} = \frac{[Z + T(\partial Z/\partial T)_P]^2}{[Z - P(\partial Z/\partial P)_T]}$$

in which the values of Z and its derivatives are consistent with Table 9.20.

Reliability of the Table

One the basis of the reliabilities estimated for specific heats and compressibilities, Tables 9.24 and 9.20, respectively, the values of γ are considered to be reliable to within 5% of their departures from ideal values at pressures below 40 atmospheres and possibly only within 10% of this difference at the highest pressure of 100 atmospheres.

U. S. Department of Commerce National Bureau of Standards

NBS - NACA Tables of Thermal Properties of Gases

Table 9.32 Sound Velocity in Molecular Oxygen

a/a_0

by

Harold W. Woolley

June 1953

Table 9.32 Sound Velocity in Molecular Oxygen a/a_0

T °K	Pressure: .01 atm		.1 atm		1 atm		4 atm		7 atm		10 atm		T °R
100	.606	58	.605	58									180
120	.664	53	.663	54	.659	54							216
140	.717	49	.717	49	.713	51	.703	54					252
160	.766	47	.766	47	.764	47	.757	50	.750	52	.743	54	288
180	.813	44	.813	44	.811	45	.807	46	.802	47	.797	49	324
200	.857	41	.857	41	.856	42	.853	43	.849	45	.846	46	360
220	.898	40	.898	40	.898	40	.896	41	.894	41	.892	42	396
240	.938	38	.938	38	.938	38	.937	38	.935	40	.934	40	432
260	.976	36	.976	36	.976	36	.975	37	.975	37	.974	39	468
280	1.012	36	1.012	36	1.012	35	1.012	36	1.012	36	1.013	35	504
300	1.048	33	1.048	33	1.047	34	1.048	34	1.048	34	1.048	35	540
320	1.081	32	1.081	32	1.081	33	1.082	32	1.082	33	1.083	33	576
340	1.113	32	1.113	32	1.114	31	1.114	32	1.115	32	1.116	32	612
360	1.145	30	1.145	30	1.145	30	1.146	30	1.147	30	1.148	31	648
380	1.175	29	1.175	29	1.175	29	1.176	29	1.177	30	1.179	29	684
400	1.204	28	1.204	28	1.204	28	1.205	29	1.207	28	1.208	29	720
420	1.232	28	1.232	28	1.232	28	1.234	28	1.235	28	1.237	28	756
440	1.260	26	1.260	26	1.260	27	1.262	26	1.263	27	1.265	26	792
460	1.286	26	1.286	26	1.287	26	1.288	27	1.290	26	1.291	27	828
480	1.312	26	1.312	26	1.313	26	1.315	25	1.316	26	1.318	26	864
500	1.338	25	1.338	25	1.339	24	1.340	25	1.342	25	1.344	25	900
520	1.363	24	1.363	24	1.363	25	1.365	24	1.367	24	1.369	24	936
540	1.387	24	1.387	24	1.388	23	1.389	24	1.391	24	1.393	24	972
560	1.411	24	1.411	24	1.411	24	1.413	24	1.415	23	1.417	23	1008
580	1.435	22	1.435	22	1.435	23	1.437	23	1.438	23	1.440	23	1044
600	1.457	23	1.457	23	1.458	22	1.460	22	1.461	23	1.463	23	1080
620	1.480	22	1.480	22	1.480	22	1.482	22	1.484	22	1.486	22	1116
640	1.502	22	1.502	22	1.502	22	1.504	22	1.506	22	1.508	22	1152
660	1.524	21	1.524	21	1.524	22	1.526	22	1.528	22	1.530	22	1188
680	1.545	22	1.545	22	1.546	21	1.548	21	1.550	21	1.552	21	1224
700	1.567	21	1.567	21	1.567	21	1.569	21	1.571	21	1.573	21	1260
720	1.588	20	1.588	20	1.588	21	1.590	21	1.592	20	1.594	21	1296
740	1.608	21	1.608	21	1.609	20	1.611	20	1.612	21	1.615	20	1332
760	1.629	20	1.629	20	1.629	20	1.631	20	1.633	20	1.635	20	1368
780	1.649	19	1.649	20	1.649	20	1.651	20	1.653	20	1.655	20	1404
800	1.668		1.669		1.669		1.671		1.673		1.675		1440

$a_0 = 314.82 \text{ m sec}^{-1} = 1032.9 \text{ ft sec}^{-1}$

Table 9.32 Sound Velocity in Molecular Oxygen a/a_0

T °K	Pressure: .01 atm		.1 atm		1 atm		4 atm		7 atm		10 atm		T °R
800	1.668	96	1.669	95	1.669	96	1.671	96	1.673	96	1.675	95	1440
900	1.764	92	1.764	92	1.765	91	1.767	91	1.769	91	1.770	92	1620
1000	1.856	86	1.856	86	1.856	87	1.858	87	1.860	86	1.862	86	1800
1100	1.942	84	1.942	84	1.943	83	1.945	83	1.946	83	1.948	83	1980
1200	2.026	79	2.026	79	2.026	80	2.028	79	2.029	80	2.031	79	2160
1300	2.105	77	2.105	77	2.106	77	2.107	77	2.109	77	2.110	77	2340
1400	2.182	74	2.182	74	2.183	74	2.184	74	2.186	74	2.187	75	2520
1500	2.256	72	2.256	72	2.257	72	2.258	72	2.260	72	2.262	71	2700
1600	2.328	69	2.328	69	2.329	69	2.330	69	2.332	68	2.333	69	2880
1700	2.397	68	2.397	68	2.398	67	2.399	68	2.400	68	2.402	67	3060
1800	2.465	65	2.465	65	2.465	65	2.467	64	2.468	65	2.469	66	3240
1900	2.530	63	2.530	63	2.530	63	2.531	64	2.533	63	2.535	62	3420
2000	2.593	62	2.593	62	2.593	62	2.595	62	2.596	62	2.597	62	3600
2100	2.655	60	2.655	60	2.655	61	2.657	60	2.658	60	2.659	61	3780
2200	2.715	59	2.715	59	2.716	59	2.717	59	2.718	59	2.720	58	3960
2300	2.774	58	2.774	58	2.775	57	2.776	57	2.777	57	2.778	58	4140
2400	2.832	56	2.832	56	2.832	56	2.833	56	2.834	57	2.836	56	4320
2500	2.888	55	2.888	55	2.888	55	2.889	55	2.891	54	2.892	55	4500
2600	2.943	53	2.943	53	2.943	54	2.944	54	2.945	54	2.947	53	4680
2700	2.996	53	2.996	53	2.997	52	2.998	52	2.999	53	3.000	53	4860
2800	3.049	51	3.049	51	3.049	52	3.050	52	3.052	51	3.053	51	5040
2900	3.100	52	3.100	52	3.101	51	3.102	52	3.103	52	3.104	52	5220
3000	3.152		3.152		3.152		3.154		3.155		3.156		5400

$a_0 = 314.82 \text{ m sec}^{-1} = 1032.9 \text{ ft sec}^{-1}$

Table 9.32 Sound Velocity in Molecular Oxygen a/a_0

T °K	Pressure 10 atm	Δ	40 atm	Δ	70 atm	Δ	100 atm	Δ	T °R
160	.743	54							288
180	.797	49	.749	70					324
200	.846	46	.819	57	.812	64			360
220	.892	42	.876	51	.876	55	.911	45	396
240	.934	40	.927	46	.931	49	.956	44	432
260	.974	39	.973	42	.980	45	1.000	42	468
280	1.013	35	1.015	40	1.025	41	1.042	41	504
300	1.048	35	1.055	37	1.066	39	1.083	39	540
320	1.083	33	1.092	35	1.105	36	1.122	37	576
340	1.116	32	1.127	34	1.141	35	1.159	35	612
360	1.148	31	1.161	32	1.176	33	1.194	33	648
380	1.179	29	1.193	30	1.209	31	1.227	32	684
400	1.208	29	1.223	30	1.240	31	1.259	31	720
420	1.237	28	1.253	29	1.271	29	1.290	29	756
440	1.265	26	1.282	27	1.300	27	1.319	28	792
460	1.291	27	1.309	27	1.327	28	1.347	27	828
480	1.318	26	1.336	26	1.355	26	1.374	27	864
500	1.344	25	1.362	25	1.381	26	1.401	26	900
520	1.369	24	1.387	25	1.407	24	1.427	25	936
540	1.393	24	1.412	24	1.431	25	1.452	24	972
560	1.417	23	1.436	24	1.456	23	1.476	24	1008
580	1.440	23	1.460	23	1.479	23	1.500	23	1044
600	1.463	23	1.483	23	1.502	23	1.523	23	1080
620	1.486	22	1.506	22	1.525	23	1.546	22	1116
640	1.508	22	1.528	21	1.548	21	1.568	22	1152
660	1.530	22	1.549	22	1.569	22	1.590	21	1188
680	1.552	21	1.571	21	1.591	21	1.611	21	1224
700	1.573	21	1.592	21	1.612	21	1.632	21	1260
720	1.594	21	1.613	21	1.633	20	1.653	21	1296
740	1.615	20	1.634	20	1.653	21	1.674	20	1332
760	1.635	20	1.654	20	1.674	19	1.694	19	1368
780	1.655	20	1.674	20	1.693	20	1.713	20	1404
800	1.675		1.694		1.713		1.733		1440

$a_0 = 314.82 \text{ m sec}^{-1} = 1032.9 \text{ ft sec}^{-1}$

Table 9.32 Sound Velocity in Molecular Oxygen a/a_0

T °K	Pressure 10 atm		40 atm		70 atm		100 atm		T °R
800	1.675	95	1.694	95	1.713	95	1.733	95	1440
900	1.770	92	1.789	91	1.808	90	1.828	89	1620
1000	1.862	86	1.880	86	1.898	86	1.917	85	1800
1100	1.948	83	1.966	83	1.984	82	2.002	81	1980
1200	2.031	79	2.049	79	2.066	78	2.083	79	2160
1300	2.110	77	2.128	76	2.144	76	2.162	75	2340
1400	2.187	75	2.204	73	2.220	73	2.237	73	2520
1500	2.262	71	2.277	71	2.293	71	2.310	69	2700
1600	2.333	69	2.348	69	2.364	68	2.379	68	2880
1700	2.402	67	2.417	67	2.432	66	2.447	67	3060
1800	2.469	66	2.484	65	2.498	65	2.514	63	3240
1900	2.535	62	2.549	62	2.563	63	2.577	63	3420
2000	2.597	62	2.611	62	2.626	60	2.640	60	3600
2100	2.659	61	2.673	60	2.686	60	2.700	59	3780
2200	2.720	58	2.733	58	2.746	58	2.759	58	3960
2300	2.778	58	2.791	57	2.804	57	2.817	57	4140
2400	2.836	56	2.848	56	2.861	55	2.874	55	4320
2500	2.892	55	2.904	55	2.916	55	2.929	54	4500
2600	2.947	53	2.959	53	2.971	53	2.983	53	4680
2700	3.000	53	3.012	52	3.024	52	3.036	52	4860
2800	3.053	51	3.064	52	3.076	51	3.088	50	5040
2900	3.104	52	3.116	51	3.127	51	3.138	51	5220
3000	3.156		3.167		3.178		3.189		5400

$$a_0 = 314.82 \text{ m sec}^{-1} = 1032.9 \text{ ft sec}^{-1}$$

Table 9.32 Sound Velocity in Molecular Oxygen

The Property Tabulated

The relative sound velocity, a/a_0, for a sound of low frequency in oxygen is tabulated as a function of temperature in degrees Kelvin and Rankine and of pressure in atmospheres. The sound velocity is represented by a, while a_0 represents the value of a at the standard conditions of $0^{\circ}C$ and one atmosphere pressure. The values for the velocity are calculated from ratios of specific heats, γ, the density, ρ, and the compressibility and its derivatives for which reference may be made to Tables 9.26, 9.18, and 9.20. The values are obtained from the theoretical relation

$$a = Z\sqrt{\frac{RT\gamma}{M[Z - P(\partial Z/\partial P)_T]}} .$$

R is the gas constant in appropriate units and M is the molecular weight, 32.000. The values tabulated are for equilibrium conditions as far as equalization of vibrational and rotational energies are concerned and thus do not apply at very high frequencies. The effect of dissociation has not been included, so that the values are not strictly for equilibrium conditions at elevated temperature and low and moderate pressure.

Reliability of the Table

The accuracy of the values tabulated varies with temperature and pressure. Numerically, the reliability is roughly that indicated for values of γ in terms of departures from ideal gas values. At $200^{\circ}K$, the values are believed to be reliable within about .003 at 10 atm, .014 at 40 atm, .05 at 70 atm and .14 at 100 atm. At $400^{\circ}K$, the values may have uncertainties of about one tenth as much, becoming still less at higher temperatures where the gas is more nearly ideal. The uncertainties, disregarding dissociation, may be as small as .004 at 100 atm for the higher temperatures.

A considerable effect due to dissociation occurs at the highest temperatures, particularly for the low pressures. Its magnitude may be estimated with formulas discussed in reference [1].

Interpolation

Linear interpolation is valid in this table.

Conversion Factors

The tabulated quantity has been expressed in dimensionless form. Conversion factors are listed at the bottom of each page in ft sec^{-1} and meter sec^{-1}. For conversions to other units see Table 1. 30 of this series.

REFERENCE

[1] H. W. Woolley, The effect of dissociation on the thermodynamic properties of pure diatomic gases, Report No. 1884, National Bureau of Standards, October 15, 1952.

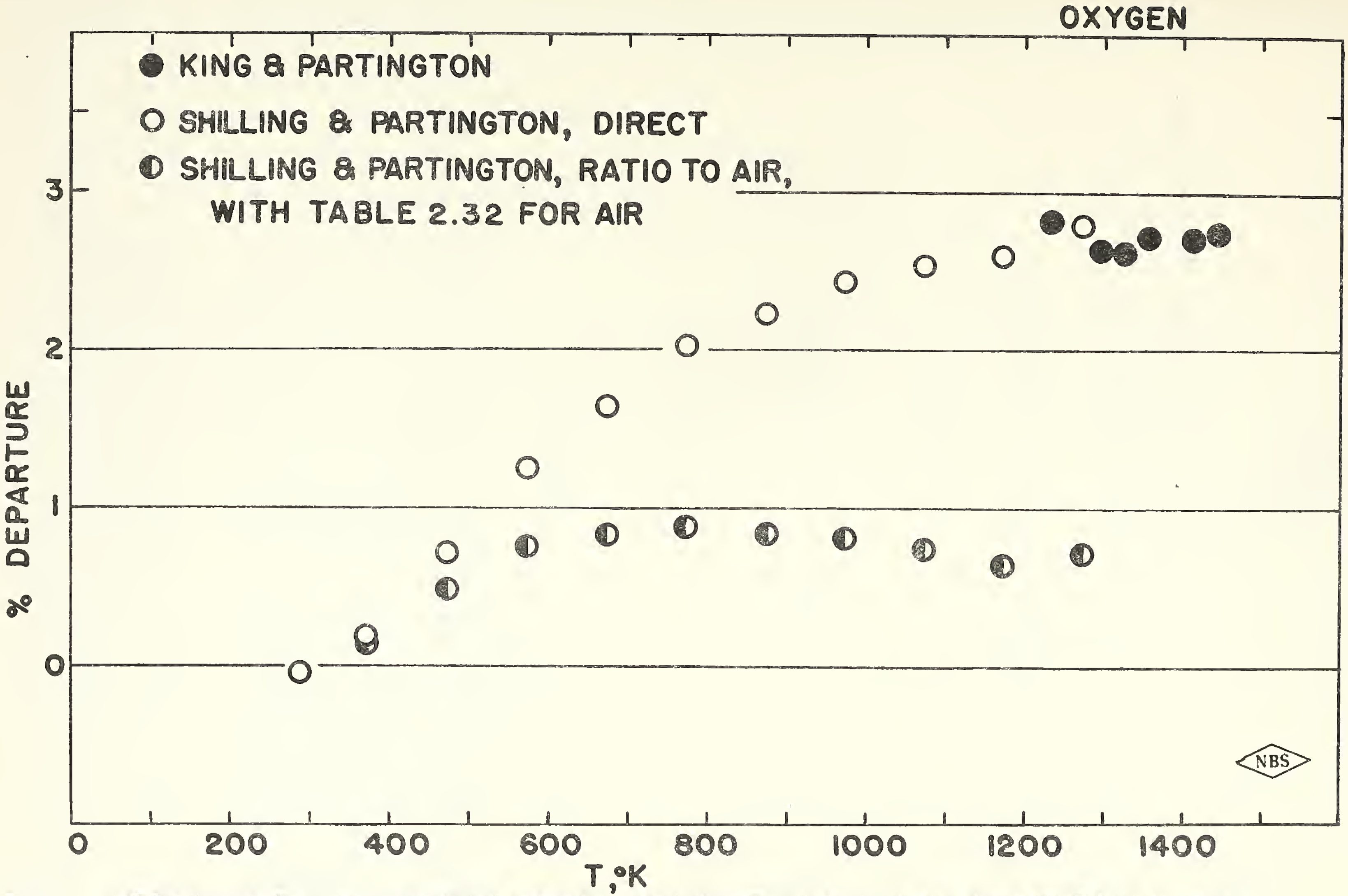


FIG. I. DEPARTURES OF EXPERIMENTAL VELOCITY OF SOUND FROM TABLE 9.32

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.39 Molecular Oxygen

Preliminary Issue July 1950

Coefficient of Viscosity

η/η_0

Compiled by R. L. Powell

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards.

Table 9.39—COEFFICIENT OF VISCOSITY OF OXYGEN

T°K	η/η_o	Δ	T°R	T°K	η/η_o	Δ	T°R	T°K	η/η_o	Δ	T°R
				400	1.3316	239	720	800	2.1447	177	1440
				410	1.3555	236	738	810	2.1624	175	1458
				420	1.3791	233	756	820	2.1799	175	1476
				430	1.4024	231	774	830	2.1974	174	1494
				440	1.4255	229	792	840	2.2148	173	1512
				450	1.4484	226	810	850	2.2321	173	1530
				460	1.4710	225	828	860	2.2394	172	1548
				470	1.4935	222	846	870	2.2666	172	1566
				480	1.5157	220	864	880	2.2838	172	1584
				490	1.5377	218	882	890	2.3010	171	1602
100	.4050	403	180	500	1.5595	216	900	900	2.3181	170	1620
110	.4453	396	198	510	1.5811	214	918	910	2.3351	169	1638
120	.4849	390	216	520	1.6025	212	936	920	2.3520	169	1656
130	.5239	381	234	530	1.6237	210	954	930	2.3689	168	1674
140	.5620	373	252	540	1.6447	209	972	940	2.3857	167	1692
150	.5993	366	270	550	1.6656	208	990	950	2.4024	166	1710
160	.6359	359	288	560	1.6864	207	1008	960	2.4190	165	1728
170	.6718	351	306	570	1.7071	205	1026	970	2.4355	165	1746
180	.7069	341	324	580	1.7276	203	1044	980	2.4520	164	1764
190	.7410	333	342	590	1.7479	201	1062	990	2.4684	163	1782
200	.7743	328	360	600	1.7680	200	1080	1000	2.485	17	1800
210	.8071	321	378	610	1.7880	198	1098	1010	2.502	16	1818
220	.8392	315	396	620	1.8078	197	1116	1020	2.518	16	1836
230	.8707	309	414	630	1.8275	195	1134	1030	2.534	16	1854
240	.9016	304	432	640	1.8470	194	1152	1040	2.550	16	1872
250	.9320	297	450	650	1.8664	193	1170	1050	2.566	16	1890
260	.9617	292	468	660	1.8857	192	1188	1060	2.582	16	1908
270	.9909	285	486	670	1.9049	192	1206	1070	2.598	16	1926
280	1.0194	281	504	680	1.9241	191	1224	1080	2.614	17	1944
290	1.0475	276	522	690	1.9432	190	1242	1090	2.631	17	1962
300	1.0751	274	540	700	1.9622	188	1260	1100	2.648	16	1980
310	1.1025	269	558	710	1.9810	186	1278	1110	2.664	16	1998
320	1.1294	264	576	720	1.9996	185	1296	1120	2.680	16	2016
330	1.1558	260	594	730	2.0181	184	1314	1130	2.696	16	2034
340	1.1818	258	612	740	2.0365	182	1332	1140	2.712	15	2052
350	1.2076	255	630	750	2.0547	181	1350	1150	2.727	15	2070
360	1.2331	251	648	760	2.0728	181	1368	1160	2.742	16	2088
370	1.2582	248	666	770	2.0909	180	1386	1170	2.758	15	2106
380	1.2830	245	684	780	2.1089	179	1404	1180	2.773	15	2124
390	1.3075	241	702	790	2.1268	179	1422	1190	2.788	15	2142
400	1.3316		720	800	2.1447		1440	1200	2.803		2160

Table 9.39—COEFFICIENT OF VISCOSITY OF OXYGEN—Continued

T°K	η/η_0	Δ	T°R	T°K	η/η_0	Δ	T°R
1200	2.803	15	2160	1600	3.374	14	2880
1210	2.818	15	2178	1610	3.388	14	2898
1220	2.833	15	2196	1620	3.402	13	2916
1230	2.848	15	2214	1630	3.415	14	2934
1240	2.863	14	2232	1640	3.429	13	2952
1250	2.877	15	2250	1650	3.442	14	2970
1260	2.892	15	2268	1660	3.456	13	2988
1270	2.907	15	2286	1670	3.469	14	3006
1280	2.922	15	2304	1680	3.483	13	3024
1290	2.937	14	2322	1690	3.496	13	3042
1300	2.951	15	2340	1700	3.509	13	3060
1310	2.966	15	2358	1710	3.522	14	3078
1320	2.981	15	2376	1720	3.536	13	3096
1330	2.996	15	2394	1730	3.549	14	3114
1340	3.011	15	2412	1740	3.563	13	3132
1350	3.026	14	2430	1750	3.576	13	3150
1360	3.040	14	2448	1760	3.589	13	3168
1370	3.054	14	2466	1770	3.602	13	3186
1380	3.068	14	2484	1780	3.615	12	3204
1390	3.082	14	2502	1790	3.627	13	3222
1400	3.096	14	2520	1800	3.640	13	3240
1410	3.110	14	2538	1810	3.653	13	3258
1420	3.124	14	2556	1820	3.666	13	3276
1430	3.138	14	2574	1830	3.679	13	3294
1440	3.152	15	2592	1840	3.692	13	3312
1450	3.167	14	2610	1850	3.705	13	3330
1460	3.181	14	2628	1860	3.718	13	3348
1470	3.195	14	2646	1870	3.731	13	3366
1480	3.209	14	2664	1880	3.744	13	3384
1490	3.223	14	2682	1890	3.757	13	3402
1500	3.237	13	2700	1900	3.770	12	3420
1510	3.250	14	2718	1910	3.782	13	3438
1520	3.264	14	2736	1920	3.795	13	3456
1530	3.278	14	2754	1930	3.808	13	3474
1540	3.292	14	2772	1940	3.821	13	3492
1550	3.306	14	2790	1950	3.834	13	3510
1560	3.320	14	2808	1960	3.847	12	3528
1570	3.334	13	2826	1970	3.859	13	3546
1580	3.347	14	2844	1980	3.872	13	3564
1590	3.361	13	2862	1990	3.885	12	3582
1600	3.374		2880	2000	3.897		3600

TABLE 9.39 COEFFICIENT OF VISCOSITY OF OXYGEN

The Property Tabulated

The viscosity of gaseous oxygen is given in this table for temperatures from 80 °K to 2000 °K (144°R to 3600°R) at one atmosphere pressure. This viscosity is given in the dimensionless form η/η_0 by dividing the absolute viscosity at a given temperature by the viscosity at 273.16°K and one atmosphere pressure, which is assumed to be 1919.2×10^{-7} poises. This value is in close agreement with the determination by Johnston and McCloskey [4], who found the viscosity to be 1918.4×10^{-7} poises at 273.16°K, based on the value 1833.0×10^{-7} poises as the viscosity of dry air at 296.1°K.

The viscosities were calculated using the Lennard-Jones potential, as applied by Hirschfelder, Bird, and Spotz [2], in which the potential energy of interaction between the two molecules is given by

$$\epsilon(r) = 4\epsilon_m \left[\left(\frac{r_0}{r}\right)^{12} - \left(\frac{r_0}{r}\right)^{6} \right]$$

where ϵ_m is the maximum energy of attraction and r_0 is the low velocity collision diameter. The coefficient of viscosity for a single gas is given by

$$\eta \times 10^7 = \frac{266.93\ V}{r_0^{\,2}\, W^{(2)}(2)} \sqrt{MT}$$

where M is the molecular weight, T is the temperature in degrees Kelvin, and V and $W^{(2)}(2)$ are functions of kT/ϵ. Hirschfelder, et al [2], have calculated the collision integrals needed for the computation of the transport properties, and have suggested the parameters for 45 gases. For this table the characteristic parameters

$$\epsilon/k = 100 \quad \text{and} \quad \frac{1}{r_0^{\,2}} \sqrt{\frac{M\epsilon}{k}} = 4.621$$

were redetermined by fitting to the data of Johnston and McCloskey and Trautz and Zink in the ranges 90°K to 300°K and 300°K to 1100°K respectively. For ease in computation, Bromley's adaptation [1] of Hirschfelder's tables was used.

There is little experimental evidence of any significant variation of viscosity with pressure at moderate pressures [3].

Reliability of the Table

A graphical comparison of the tabulated values and the experimental results of six authors (4, 6, 9, 10, 11, 14) is given in Figure 1. The viscosity table is reliable within 1% below 1000°K. The extrapolated values to 2000°K are reliable within 2%.

Interpolation

Linear interpolation is valid above 200°K, below that temperature Lagrangian interpolation is recommended.

Conversion Factors

The viscosity of oxygen has been expressed in dimensionless form. Conversion factors for the more frequently used units are given. For conversion factors not listed here, see table 1.30 of this series.

To convert tabulated value of—	To—	Having the dimensions indicated below	Multiply by—
η/η_0	η	poise or g(M) sec^{-1} cm^{-1}	1919.2×10^{-7}
		Kg(M) hr^{-1} m^{-1}	6.9091×10^{-2}
		lb(F) sec ft^{-2}	4.0084×10^{-7}
		lb(M) sec^{-1} ft^{-1}	1.2896×10^{-5}
		lb(M) hr^{-1} ft^{-1}	4.6427×10^{-2}

REFERENCES

[1] LeRoy A. Bromley, "Calculation of gas viscosity as a function of temperature," U. S. Atomic Energy Comm., UCRL-525 (1949).

[2] J. O. Hirschfelder, R. B. Bird, E. L. Spotz, Viscosity and other physical properties of gases and gas mixtures, Trans. ASME, 48,921 (1949).

[3] A. Van Itterbeek, W. H. Keesom, Measurements on the viscosity of oxygen gas, Physica, 2, 97 (1935).

[4] H. L. Johnston, K. E. McCloskey, Viscosities of gases, J. Phys. Chem., 44, 1038 (1940).

[5] H. Markowski, Die innere Reibung von Sauerstoff, Wasserstoff, chemischem und atmosphärischem Stickstoff und ihre Änderung mit der Temperatur, Ann. Physik, 4-14, 742 (1904).

[6] P. J. Rigden, The viscosity of air, oxygen, and nitrogen, Phil. Mag., 7-25, 961 (1938).

[7] E. Thomson, Über die innere Reibung von Gasgemischen, Ann. Physik, 4-36, 815 (1911).

[8] M. Trautz, R. Heberling, Die Reibung von NH_3 und seinen Gemischen mit H_2, N_2, O_2, C_2H_4, Ann. Physik, 5-10, 155 (1931).

[9] M. Trautz, A. Melster, Die Reibung von H_2, N_2, CO, C_2H_4, O_2, und ihren binären Gemischen, Ann. Physik, 5-7, 409 (1930).

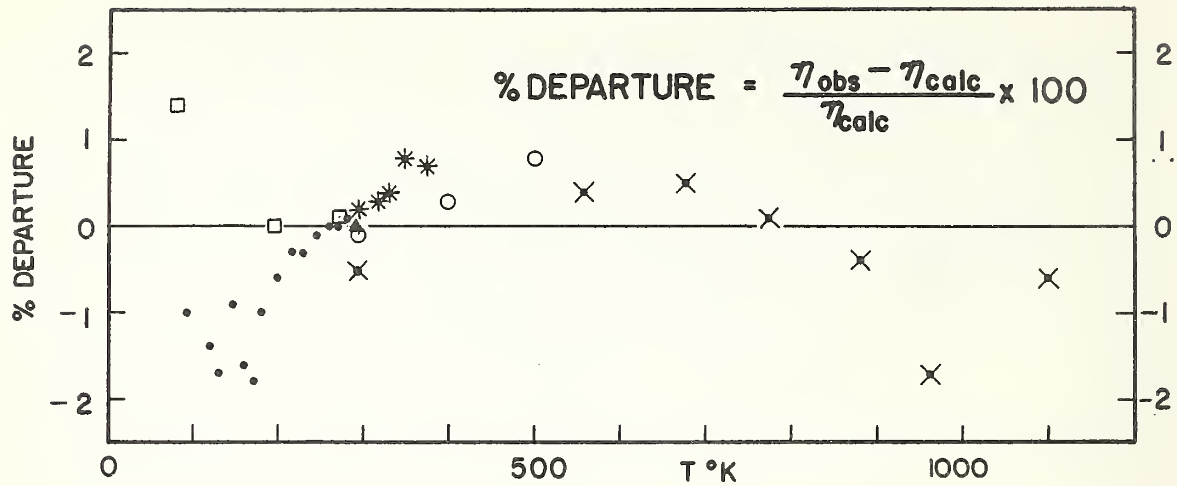
[10] M. Trautz, R. Zink. Gasreibung bei höheren Temperaturen, Ann. Physik, 5-7, 427 (1930).

[11] H. Vogel, Viskosität einiger Gase, Ann. Physik, 4-43, 1235 (1914).

[12] E. Völker, Über den Koëffizienten der inneren Reibung von Sauerstoff und Wasserstoff bei niederen Temperaturen, Diss., Halle, 1910.

[13] K. Yen, Determination of the coefficient of viscosity of hydrogen, nitrogen and oxygen, Phil. Mag., 6-38, 582 (1919).

[14] R. Wobser, F. Müller, Die innere Reibung von Gasen und Dampfen und ihre Messung im Höppler-Viskosimeter, Kolloid Beihefte, 52, 165 (1941).



• Johnston & Mc Closkey — 1940
□ Vogel — 1914
X Trautz & Zink — 1930
○ Trautz & Melster — 1930
✳ Wobser & Müller — 1941
▲ Riqden — 1938

FIGURE I. DEPARTURES OF EXPERIMENTAL VISCOSITIES FROM TABLE 9.39

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.42 Molecular Oxygen

July 1951

Thermal Conductivity

k/k_0

Compiled by R. L. Nuttall

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available.

The dimensionless character of the tables and their general format should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards.

Table 9.42 Thermal Conductivity of Molecular Oxygen

T	k/k_0	Δ	T	T	k/k_0	Δ	T
°K			°R	°K			°R
80	.293	38	144				
90	.331	37	162				
100	.368	38	180	350	1.25	3	630
110	.406	38	198	360	1.28	4	648
120	.444	38	216	370	1.32	3	666
130	.482	38	234	380	1.35	3	684
140	.520	37	252	390	1.38	3	702
150	.557	38	270	400	1.41	3	720
160	.595	37	288	410	1.44	3	738
170	.632	37	306	420	1.47	3	756
180	.669	37	324	430	1.50	3	774
190	.706	37	342	440	1.53	3	792
200	.743	36	360	450	1.56	3	810
210	.779	36	378	460	1.59	3	828
220	.815	35	396	470	1.62	2	846
230	.850	35	414	480	1.64	3	864
240	.885	35	432	490	1.67	3	882
250	.920	34	450	500	1.70	3	900
260	.954	35	468	510	1.73	3	918
270	.989	3	486	520	1.76	2	936
280	1.02	4	504	530	1.78	3	954
290	1.06	3	522	540	1.81	3	972
300	1.06	3	540	550	1.84	2	990
310	1.12	4	558	560	1.86	3	1008
320	1.16	3	576	570	1.89	3	1026
330	1.19	3	594	580	1.92	2	1044
340	1.22	3	612	590	1.94	3	1062
350	1.25		630	600	1.97		1080

CONVERSION FACTORS

To Convert Tabulated Value of	To	Having the Dimensions Indicated Below	Multiply by
k/k_0	k	cal cm^{-1} sec^{-1} $^oK^{-1}$	5.867×10^{-5}
		Btu ft^{-1} hr^{-1} $^oR^{-1}$	1.419×10^{-2}
		watts cm^{-1} $^oK^{-1}$	2.455×10^{-4}

THE PROPERTY TABULATED

This table gives in dimensionless form as a function of temperature in degrees Kelvin and degrees Rankine, the thermal conductivity, k/k_0, of molecular oxygen. The values were calculated from the equation

$$k = \frac{C_0 T^{1/2}}{1 + \frac{C_1}{T} 10^{-C_2/T}} \qquad \begin{aligned} C_0 &= 0.6726 \times 10^{-5} \\ C_1 &= 265.9 \\ C_2 &= 10 \end{aligned}$$

The symbol k is the thermal conductivity in cal cm^{-1} sec^{-1} $°C^{-1}$ and T is the temperature in degrees Kelvin. The tabulated quantities have been made dimensionless by dividing by $k_0 = 5.867 \times 10^{-5}$ cal cm^{-1} sec^{-1} $°C^{-1}$ which is the thermal conductivity of oxygen at 0°C and 1 atmosphere. These values apply at low to moderate pressures.

RELIABILITY OF THE TABLE

The experimental data covers the range from 86° to 376°K. The accuracy of the table in this range is of the order of 2%. The accompanying graph shows the deviations of the tabulated values from experimental data.

INTERPOLATION

Linear interpolation is valid in this table.

CONVERSION FACTORS

The function in this table has been expressed in dimensionless form. In order that it may be converted readily to any system of units, conversion factors are listed for the frequently used units. For conversion factors not listed here see Table 1.30 of this series.

REFERENCES

[1] A. Eucken, Über die Temperaturabhängigkeit der Wärmeleitfähigkeit einiger Gase, Physik. Z. 12, 1101 (1911).

[2] S. Weber, Untersuchungen über die Wärmeleitfähigkeit der Gase, Ann. Physik 54, 437 (1917).

[3] H. Gregory and S. Marshall, The thermal conductivities of oxygen and nitrogen, Proc. Roy. Soc. (London) A118, 594 (1928).

[4] B. G. Dickens, The effect of accommodation on heat conduction through gases, Proc. Roy. Soc. (London) A143, 517 (1934).

[5] W. G. Kannuluik and L. H. Martin, The thermal conductivity of some gases at 0°C, Proc. Roy. Soc. (London) A144, 496 (1934).

[6] W. Northdurft, Zur Absolutemessung des Wärmeleitvermögens von Gasen, Ann. Physik 28, 137 (1937).

[7] H. L. Johnston and E. R. Grilly, An improved hot-wire cell for accurate measurements of thermal conductivities of gases over a wide temperature range, J. Chem. Phys. 14, 219 (1946).

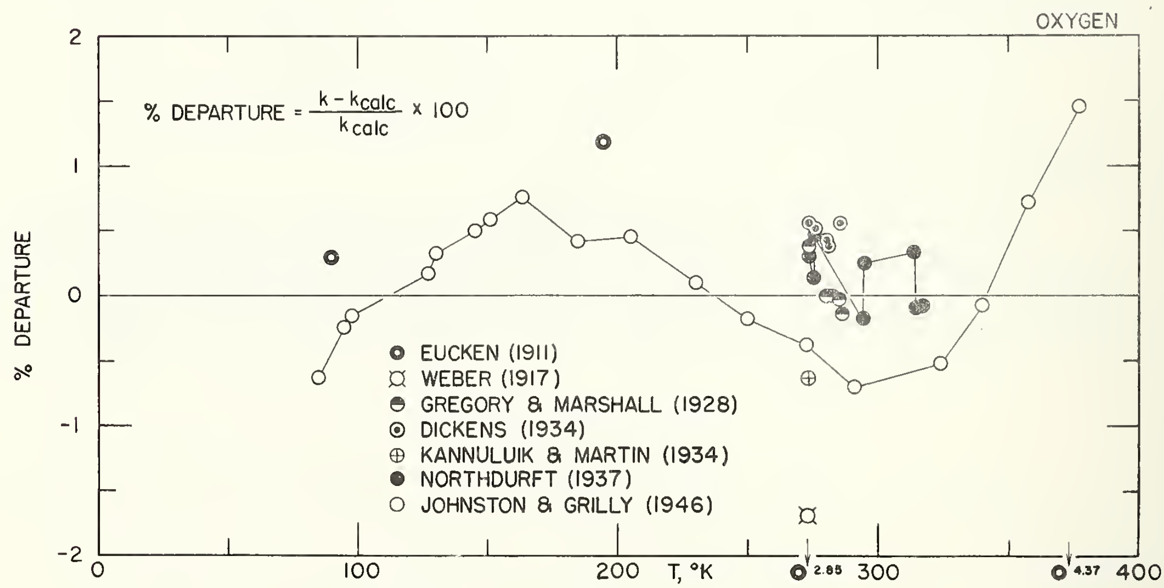


FIGURE I. DEPARTURES OF EXPERIMENTAL THERMAL CONDUCTIVITIES FROM TABLE 9.42

U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

THE NBS - NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.44 Prandtl Number of Oxygen

$$N_{Pr} = \eta C_p/k$$

by

F. Donald Queen

June 1953

Table 9.44 Prandtl Number of Oxygen $N_{Pr} = \eta\, C_p/k$

T °K	N_{Pr}	$[N_{Pr}]^{\frac{2}{3}}$	$[N_{Pr}]^{\frac{1}{3}}$	$[N_{Pr}]^{\frac{1}{2}}$	T °R
100	.815	.873	.934	.903	180
110	.800	.862	.928	.894	198
120	.791	.855	.925	.889	216
130	.784	.850	.922	.885	234
140	.778	.846	.920	.882	252
150	.773	.842	.918	.879	270
160	.766	.837	.915	.875	288
170	.761	.834	.913	.872	306
180	.756	.830	.911	.869	324
190	.751	.826	.909	.867	342
200	.745	.822	.907	.863	360
210	.740	.818	.905	.860	378
220	.736	.815	.903	.858	396
230	.732	.812	.901	.856	414
240	.728	.809	.900	.853	432
250	.725	.807	.898	.851	450
260	.722	.805	.897	.850	468
270	.718	.802	.895	.847	486
280	.717	.801	.895	.847	504
290	.710	.796	.892	.843	522
300	.709	.795	.892	.842	540
310	.709	.795	.892	.842	558
320	.703	.791	.889	.838	576
330	.702	.790	.889	.838	594
340	.702	.790	.889	.838	612
350	.702	.790	.889	.838	630
360	.701	.789	.888	.837	648
370	.696	.785	.886	.834	666
380	.696	.785	.886	.834	684
390	.696	.785	.886	.834	702
400	.695	.785	.886	.834	720
410	.695	.785	.886	.834	738
420	.695	.785	.886	.834	756
430	.695	.785	.886	.834	774
440	.694	.784	.885	.833	792
450	.694	.784	.885	.833	810

Table 9.44 Prandtl Number of Oxygen $N_{Pr} = \eta C_p/k$

T °K	N_{Pr}	$[N_{Pr}]^{\frac{2}{3}}$	$[N_{Pr}]^{\frac{1}{3}}$	$[N_{Pr}]^{\frac{1}{2}}$	T °R
450	.694	.784	.885	.833	810
460	.694	.784	.885	.833	828
470	.695	.785	.886	.834	846
480	.697	.786	.887	.835	864
490	.697	.786	.887	.835	882
500	.697	.786	.887	.835	900
510	.697	.786	.887	.835	918
520	.697	.786	.887	.835	936
530	.700	.788	.888	.837	954
540	.700	.788	.888	.837	972
550	.700	.788	.888	.837	990
560	.701	.789	.888	.837	1008
570	.702	.790	.889	.838	1026
580	.702	.790	.889	.838	1044
590	.704	.791	.890	.839	1062
600	.704	.791	.890	.839	1080

The Property Tabulated

The Prandtl number $N_{Pr} = \eta C_p/k$ and some of its fractional powers are listed for molecular oxygen at one atmosphere. The table was computed from values of viscosity, η, specific heat, C_p, and thermal conductivity, k, given respectively in tables 9.39, 9.24 and 9.42 of this series. The ratio $\eta C_p/k$ is dimensionless when η, C_p and k are in a consistent set of units. A few frequently used powers are tabulated for convenience. Other fractional powers may be obtained from the alignment chart in figure 1.

Reliability of the Table

The uncertainty in this table results from the uncertainty of thermal conductivity and viscosity, on the basis of which the Prandtl number may be reliable to about 2 per cent.

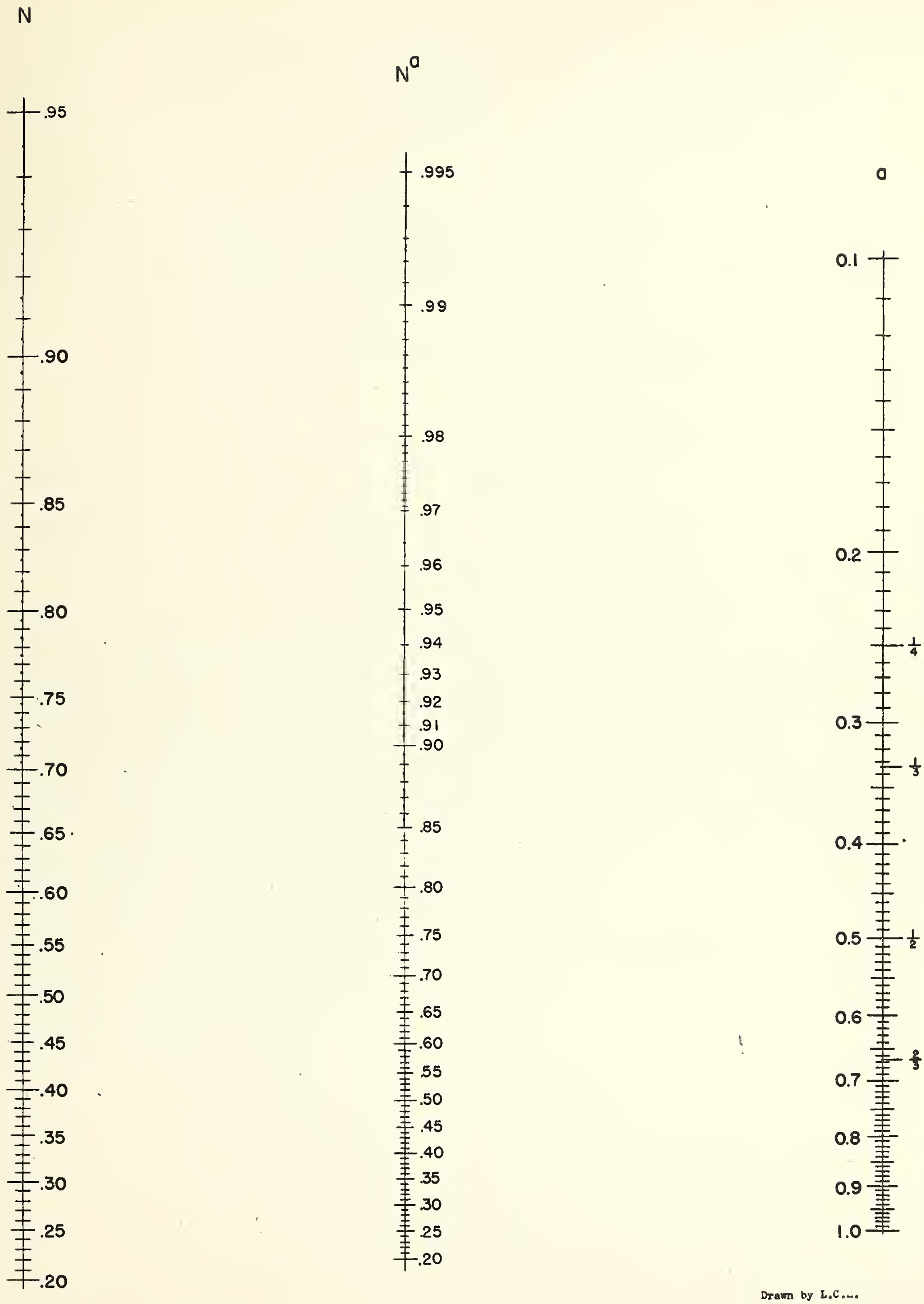

N
.95
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
N^a
.995
.99
.98
.97
.96
.95
.94
.93
.92
.91
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
a
0.1
0.2
$\frac{1}{4}$
0.3
$\frac{1}{3}$
0.4
0.5
$\frac{1}{2}$
0.6
$\frac{2}{3}$
0.7
0.8
0.9
1.0
Drawn by L.C...

Figure 1.

U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

THE NBS-NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 9.50 Vapor Pressure of Oxygen

December 1949

by Harold J. Hoge

FOREWORD

This is one of a series of tables of Thermal Properties of Gases being compiled at the National Bureau of Standards at the suggestion and with the cooperation of the National Advisory Committee for Aeronautics. Recent advances in methods of propulsion and the high speeds attained thereby have emphasized the importance of accurate data on thermal properties of wind-tunnel and jet-engine gases. It is the purpose of the project on Thermal Properties of Gases to make a critical compilation of existing published and unpublished data, and to present such data in convenient form for application. The loose-leaf form has been chosen as being most convenient, and revisions are anticipated as new data become available. This table is also available on IBM punched cards.

The tables should facilitate calculations in aerodynamics, heat-transfer, and jet-engine problems. Suggestions for the extension or improvement of these tables are desired as well as information regarding unpublished data. Information and other correspondence regarding these tables should be addressed to *Joseph Hilsenrath*, Heat and Power Division, National Bureau of Standards.

VAPOR PRESSURE OF OXYGEN

SOURCE OF THE DATA

These tables are based on a recently completed experimental investigation of the vapor pressure of liquid oxygen at the National Bureau of Standards. Figure 1 shows the experimental data plotted as deviations from the tables. A comparison with the results of other observers is given in the complete report [1].

USE OF THE TABLES

Table 9.50/1 is to be used when accurate interpolated values are required. This table gives $\log_{10} P$ at uniform intervals of 1/T, the argument being 2/T at first; then changing to 1/T and finally back to 2/T again to give a progressively closer spacing of entries. The values of T given in table 9.50/1 are only for convenience in locating the part of the table to be used. Interpolations must be made in terms of 1/T or 2/T (1.8/T or 3.6/T on the Rankine scale) rather than in terms of T for greatest convenience and accuracy. When this is done, linear interpolation will introduce no significant error below about 130°K ($1/T°K = 3.6/T°R = 0.0142$). Above this temperature slight errors may be introduced, which however do not exceed 4 mm Hg and reach this value only in the immediate neighborhood of the critical point. Table 9.50/2 gives P at temperature intervals of 5°K(9°R). This table is for ready reference when values at these particular temperatures are adequate.

RELIABILITY

Below a pressure of about 1.4 m Hg the tables are based on mercury manometry and are accurate to about ±0.2mm Hg. Above about 1.4 m Hg the uncertainty increases to ±1 or 2 mm Hg, and then gradually increases further at higher pressures, reaching a value of perhaps ±10 mm Hg at the critical point. In these estimates no allowance has been made for possible disagreement between the temperature scales used and the thermodynamic scale. The International Temperature Scale was used down to 90.19°K and the NBS provisional scale at lower temperatures.

VAPOR PRESSURE OF SOLID OXYGEN

The only data [2] for solid oxygen do not appear to be very reliable, and hence the tabulation has not been extended below the triple point. Since the solid must have a lower vapor pressure than the hypothetical supercooled liquid, extrapolation of table 9.50/1 gives a rough upper limit for the vapor pressure of the solid. This procedure gives an upper limit of 0.020 mm Hg at 43.8°K, which is the temperature of the higher of the two solid-solid transitions of oxygen. At this temperature Aoyama and Kanda [2] found 0.0111. The true vapor pressure here is almost certainly less than 0.015 mm Hg.

REFERENCES

[1] Harold J. Hoge. Vapor pressure and fixed points of oxygen and heat capacity in the critical region. J. Research NBS 44(1950) (in press).

[2] Shinichi Aoyama and Eizo Kanda. The vapor tensions of oxygen and nitrogen in the solid state. Sci. Repts. Tohoku Imp. Univ. Sendai 24, 107-15 (1935).

TABLE 9.50/2 VAPOR PRESSURE OF OXYGEN (NOT FOR INTERPOLATION)

Remarks	T \ P (°K)	mm Hg	atm	psia	P / T (°R)	T \ P (°K)	mm Hg	atm	psia	P / T (°R)
Triple pt	54.363	1.14	0.00150	.022	97.853	95	1223.3	1.6096	23.65	171
Boiling pt	90.190	760.0	1.	14.696	162.342	100	1905.0	2.5066	36.84	180
Critical pt	154.7_8	381_{09}	50.1_4	$736._9$	278.6_0	105	2838.2	3.7345	54.88	189
						110	4072.9	5.3591	78.76	198
	55	1.38	0.00182	0.027	99	115	5661.6	7.4495	109.48	207
	60	5.44	0.00716	0.105	108	120	7658.6	10.077	148.09	216
	65	17.4	0.0229	0.34	117	125	10120	13.316	195.7	225
	70	46.8	0.0616	0.90	126	130	13102	17.239	253.4	234
	75	108.7	0.1430	2.10	135	135	16670	21.934	322.3	243
	80	225.3	0.2964	4.36	144	140	20892	27.489	404.0	252
	85	425.4	0.5597	8.23	153	145	25843	34.004	499.7	261
	90	745.0	0.9803	14.41	162	150	31631	41.620	611.6	270

TABLE 9.50/I VAPOR PRESSURE OF OXYGEN (FOR INTERPOLATION)

$\frac{2}{T}$	T	$\log_{10}$ p				T	$\frac{3.6}{T}$
°K^{-1}	°K	mm Hg	atm	psia	Δ	°R	°R^{-1}
0.037	54.054	0.014	7.133*	8.300*	197	97.297	0.037
0.036	55.556	0.211	7.330	8.497	197	100.000	0.036
0.035	57.143	0.408	7.527	8.694	197	102.857	0.035
0.034	58.824	0.605	7.724	8.891	197	105.882	0.034
0.033	60.606	0.802	7.921	9.088	197	109.091	0.033
0.032	62.500	0.999	8.118	9.285	197	112.500	0.032
0.031	64.516	1.196	8.315	9.482	196	116.129	0.031
0.030	66.667	1.392	8.511	9.678	195	120.000	0.030
0.029	68.966	1.587	8.706	9.873	194	124.138	0.029
0.028	71.429	1.781	8.900	0.067		128.571	0.028
$\frac{1}{T}$							$\frac{1.8}{T}$
0.0140	71.429	1.7807	8.8999	0.0671	385	128.571	0.0140
0.0139	71.942	1.8192	8.9384	0.1056	384	129.496	0.0139
0.0138	72.464	1.8576	8.9768	0.1440	383	130.435	0.0138
0.0137	72.993	1.8959	9.0151	0.1823	383	131.387	0.0137
0.0136	73.529	1.9342	9.0534	0.2206	382	132.353	0.0136
0.0135	74.074	1.9724	9.0916	0.2588	382	133.333	0.0135
0.0134	74.627	2.0106	9.1298	0.2970	382	134.328	0.0134
0.0133	75.188	2.0488	9.1680	0.3352	381	135.338	0.0133
0.0132	75.758	2.0869	9.2061	0.3733	381	136.364	0.0132
0.0131	76.336	2.1250	9.2442	0.4114	381	137.404	0.0131
0.0130	76.923	2.1631	9.2823	0.4495	381	138.462	0.0130
0.0129	77.519	2.2012	9.3204	0.4876	380	139.535	0.0129
0.0128	78.125	2.2392	9.3584	0.5256	380	140.625	0.0128
0.0127	78.740	2.2772	9.3964	0.5636	378	141.732	0.0127
0.0126	79.365	2.3150	9.4342	0.6014	377	142.857	0.0126
0.0125	80.000	2.3527	9.4719	0.6391	377	144.000	0.0125
0.0124	80.645	2.3904	9.5096	0.6768	376	145.161	0.0124
0.0123	81.301	2.4280	9.5472	0.7144	376	146.341	0.0123
0.0122	81.967	2.4656	9.5848	0.7520	375	147.541	0.0122
0.0121	82.645	2.5031	9.6223	0.7895	375	148.760	0.0121
0.0120	83.333	2.5406	9.6598	0.8270	375	150.000	0.0120
0.0119	84.034	2.5781	9.6973	0.8645	375	151.260	0.0119
0.0118	84.746	2.6156	9.7348	0.9020	374	152.542	0.0118
0.0117	85.470	2.6530	9.7722	0.9394	374	153.846	0.0117
0.0116	86.207	2.6904	9.8096	0.9768	373	155.172	0.0116
0.0115	86.957	2.7277	9.8469	1.0141		156.522	0.0115
0.0115	86.957	2.72767	9.84686	1.01405	3725	156.522	0.0115
0.0114	87.719	2.76492	9.88411	1.05130	3718	157.895	0.0114
0.0113	88.496	2.80210	9.92129	1.08848	3712	159.292	0.0113
0.0112	89.286	2.83922	9.95841	1.12560	3704	160.714	0.0112
0.0111	90.090	2.87626	9.99545	1.16264	3697	162.162	0.0111
0.0110	90.909	2.91323	0.03242	1.19961	3690	163.636	0.0110
0.0109	91.743	2.95013	0.06932	1.23651	3685	165.138	0.0109
0.0108	92.593	2.98698	0.10617	1.27336	3679	166.667	0.0108
0.0107	93.458	3.02377	0.14296	1.31015	3674	168.224	0.0107
0.0106	94.340	3.06051	0.17970	1.34689	3669	169.811	0.0106
0.0105	95.238	3.09720	0.21639	1.38358	3663	171.428	0.0105
0.0104	96.154	3.13383	0.25302	1.42021	3659	173.077	0.0104
0.0103	97.087	3.17042	0.28961	1.45680	3654	174.757	0.0103
0.0102	98.039	3.20696	0.32615	1.49334	3649	176.470	0.0102
0.0101	99.010	3.24345	0.36264	1.52983	3644	178.218	0.0101
0.0100	100.000	3.27989	0.39908	1.56627		180.000	0.0100

$\frac{1}{T}$	T	$\log_{10}$ p				T	$\frac{1.8}{T}$
°K^{-1}	°K	mm Hg	atm	psia	Δ	°R	°R^{-1}
0.0100	100.000	3.27989	0.39908	1.56627	3641	180.000	0.0100
0.0099	101.010	3.31630	0.43549	1.60268	3639	181.818	0.0099
0.0098	102.041	3.35269	0.47188	1.63907	3636	183.673	0.0098
0.0097	103.093	3.38905	0.50824	1.67543	3634	185.567	0.0097
0.0096	104.167	3.42539	0.54458	1.71177	3630	187.500	0.0096
0.0095	105.263	3.46169	0.58088	1.74807	3627	189.474	0.0095
0.0094	106.383	3.49796	0.61715	1.78434	3623	191.489	0.0094
0.0093	107.527	3.53419	0.65338	1.82057	3622	193.548	0.0093
0.0092	108.696	3.57041	0.68960	1.85679	3620	195.652	0.0092
0.0091	109.890	3.60661	0.72580	1.89299	3620	197.802	0.0091
0.0090	111.111	3.64281	0.76200	1.92919	3619	200.000	0.0090
0.0089	112.360	3.67900	0.79819	1.96538	3618	202.247	0.0089
0.0088	113.636	3.71518	0.83437	2.00156	3619	204.545	0.0088
0.0087	114.943	3.75137	0.87056	2.03775	3619	206.896	0.0087
0.0086	116.279	3.78756	0.90675	2.07394	3621	209.302	0.0086
0.0085	117.647	3.82377	0.94296	2.11015	3622	211.765	0.0085
0.0084	119.048	3.85999	0.97918	2.14637	3624	214.286	0.0084
0.0083	120.482	3.89623	1.01542	2.18261	3626	216.867	0.0083
0.0082	121.951	3.93249	1.05168	2.21887	3631	219.512	0.0082
0.0081	123.457	3.96880	1.08799	2.25518	3636	222.222	0.0081
0.0080	125.000	4.00516	1.12435	2.29154	3640	225.000	0.0080
0.0079	126.582	4.04156	1.16075	2.32794	3646	227.848	0.0079
0.0078	128.205	4.07802	1.19721	2.36440		230.769	0.0078
$\frac{2}{T}$							$\frac{3.6}{T}$
0.0156	128.2051	4.07802	1.19721	2.36440	1826	230.769	0.0156
0.0155	129.0323	4.09628	1.21547	2.38266	1826	232.258	0.0155
0.0154	129.8701	4.11454	1.23373	2.40092	1829	233.766	0.0154
0.0153	130.7190	4.13283	1.25202	2.41921	1832	235.294	0.0153
0.0152	131.5789	4.15115	1.27034	2.43753	1834	236.842	0.0152
0.0151	132.4503	4.16949	1.28868	2.45587	1836	238.410	0.0151
0.0150	133.3333	4.18785	1.30704	2.47423	1840	240.000	0.0150
0.0149	134.2282	4.20625	1.32544	2.49263	1842	241.611	0.0149
0.0148	135.1351	4.22467	1.34386	2.51105	1846	243.243	0.0148
0.0147	136.0544	4.24313	1.36232	2.52951	1849	244.898	0.0147
0.0146	136.9863	4.26162	1.38081	2.54800	1853	246.575	0.0146
0.0145	137.9310	4.28015	1.39934	2.56653	1856	248.276	0.0145
0.0144	138.8889	4.29871	1.41790	2.58509	1860	250.000	0.0144
0.0143	139.8601	4.31731	1.43650	2.60369	1864	251.748	0.0143
0.0142	140.8451	4.33595	1.45514	2.62233	1869	253.521	0.0142
0.0141	141.8440	4.35464	1.47383	2.64102	1875	255.319	0.0141
0.0140	142.8571	4.37339	1.49258	2.65977	1880	257.143	0.0140
0.0139	143.8849	4.39219	1.51138	2.67857	1886	258.993	0.0139
0.0138	144.9275	4.41105	1.53024	2.69743	1893	260.870	0.0138
0.0137	145.9854	4.42998	1.54917	2.71636	1900	262.774	0.0137
0.0136	147.0588	4.44898	1.56817	2.73536	1909	264.706	0.0136
0.0135	148.1481	4.46807	1.58726	2.75445	1919	266.667	0.0135
0.0134	149.2537	4.48726	1.60645	2.77364	1930	268.657	0.0134
0.0133	150.3759	4.50656	1.62575	2.79294	1942	270.677	0.0133
0.0132	151.5152	4.52598	1.64517	2.81236	1956	272.727	0.0132
0.0131	152.6718	4.54554	1.66473	2.83192	1977	274.809	0.0131
0.0130	153.8462	4.56531	1.68450	2.85169	2008	276.923	0.0130
0.0129	155.0388	4.58539	1.70458	2.87177	2050	279.070	0.0129
0.0128	156.2500	4.60589	1.72508	2.89227		281.250	0.0128

*Logarithms have been increased by 10 wherever necessary to avoid negative mantissas.

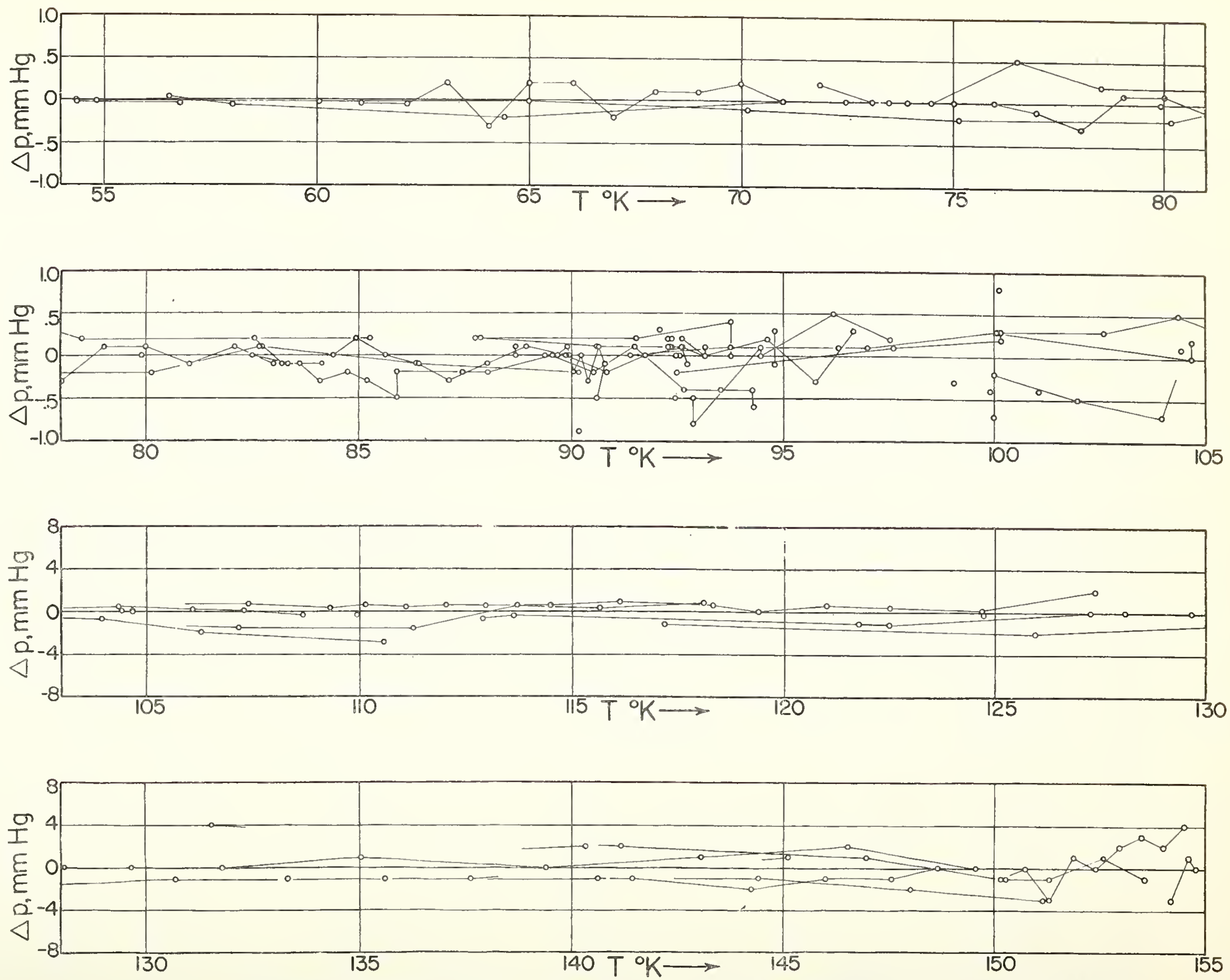


Figure l. Deviations (obs-calc) of the experimental data from table 9.50/1

THE NBS - NACA TABLES OF THERMAL PROPERTIES OF GASES

Table 1.30 Conversion Factors

Table 1.30/ a CONVERSION FACTORS FOR UNITS OF LENGTH*

Multiply by approxriate entry to obtain →	cm	mm	μ	mμ	Å
1 Centimeter (cm)	1	10	10^4	10^7	10^8
1 Millimeter (mm)	10^{-1}	1	10^3	10^6	10^7
1 Micron (μ)	10^{-4}	10^{-3}	1	10^3	10^4
1 Millimicron (mμ)	10^{-7}	10^{-6}	10^{-3}	1	10
1 Angstrom Unit (Å)	10^{-8}	10^{-7}	10^{-4}	10^{-1}	1

Table 1.30/ b CONVERSION FACTORS FOR UNITS OF LENGTH

Multiply by appropriate entry to obtain →	cm	m	in	ft	yd
1 cm	1	0.01	0.3937	0.032808333	0.010936111
1 m	100.	1	39.37	3.2808333	1.0936111
1 in	2.5400051	0.025400051	1	0.083333333	0.027777778
1 ft	30.480061	0.30480061	12.	1	0.33333333
1 yd	91.440183	0.91440183	36.	3.	1

* The conversion factors in Tables 1.30/ a - 1.30/ k are reproduced from "Selected Values of Properties of Hydrocarbons", NBS Circular C461, November, 1947.

Table 1.30/Ac CONVERSION FACTORS FOR UNITS OF AREA

Multiply by appropriate entry to obtain →	cm^2	m^2	sq in	sq ft	sq yd
1 cm^2	1	10^{-4}	0.15499969	1.0763867 $\times10^{-3}$	1.1959853 $\times10^{-4}$
1 m^2	10^4	1	1549.9969	10.763867	1.1959853
1 sq in	6.4516258	6.4516258 $\times10^{-4}$	1	6.9444444 $\times10^{-3}$	7.7160494 $\times10^{-4}$
1 sq ft	929.03412	0.092903412	144.	1	0.11111111
1 sq yd	8361.3070	0.83613070	1296.	9.	1

Table 1.30/Ad CONVERSION FACTORS FOR UNITS OF VOLUME

Multiply by appropriate entry to obtain →	ml	liter	gal
1 cm^3	0.9999720	0.9999720×10^{-3}	2.6417047×10^{-4}
1 cu in	16.38670	1.638670×10^{-2}	4.3290043×10^{-3}
1 cu ft	28316.22	28.31622	7.4805195
1 ml	1	0.001	2.641779×10^{-4}
1 liter	1000.	1	0.2641779
1 gal	3785.329	3.785329	1

Table 1.30/Ad CONVERSION FACTORS FOR UNITS OF VOLUME (Continued)

Multiply by appropriate entry to obtain →	cm^3	cu in	cu ft
1 cm^3	1	0.061023378	3.5314455×10^{-5}
1 cu in	16.387162	1	5.7870370×10^{-4}
1 cu ft	28317.017	1728.	1
1 ml	1.000028	0.06102509	3.531544×10^{-5}
1 liter	1000.028	61.02509	0.03531544
1 gal	3785.4345	231.	0.13368056

Table 1.30/4e CONVERSION FACTORS FOR UNITS OF MASS

Multiply by appropriate entry to obtain →	g	kg	lb	metric ton	ton
1 g	1	10^{-3}	2.2046223×10^{-3}	10^{-6}	1.1023112×10^{-6}
1 kg	10^{3}	1	2.2046223	10^{-3}	1.1023112×10^{-3}
1 lb	453.59243	0.45359243	1	4.5359243×10^{-4}	0.0005
1 metric ton	10^{6}	10^{3}	2204.6223	1	1.1023112
1 ton	907184.86	907.18486	2000.	0.90718486	1

Table 1.30/4f CONVERSION FACTORS FOR UNITS OF DENSITY

Multiply by appropriate entry to obtain →	g/cm^3	g/ml	lb/cu in	lb/cu ft	lb/gal
1 g/cm^3	1	1.000028	0.036127504	62.428327	8.3454535
1 g/ml	0.9999720	1	0.03612649	62.42658	8.345220
1 lb/cu in	27.679742	27.68052	1	1728.	231.
1 lb/cu ft	0.016018369	0.01601882	5.7870370×10^{-4}	1	0.13368056
1 lb/gal	0.11982572	0.1198291	4.3290043×10^{-3}	7.4805195	1

Table 1.30/Ag CONVERSION FACTORS FOR UNITS OF PRESSURE

Multiply by appropriate entry to obtain →	$dyne/cm^2$	bar	atm	$kg(wt)/cm^2$
1 $dyne/cm^2$	1	10^{-6}	0.9869233×10^{-6}	1.0197162×10^{-6}
1 bar	10^6	1	0.9869233	1.0197162
1 atm	1013250.	1.013250	1	1.0332275
1 $kg(wt)/cm^2$	980665.	0.980665	0.9678411	1
1 mm Hg	1333.2237	1.3332237×10^{-3}	1.3157895×10^{-3}	1.3595098×10^{-3}
1 in Hg	33863.95	0.03386395	0.03342112	0.03453162
1 lb(wt)/sq in	68947.31	0.06894731	0.06804570	0.07030669

Table 1.30/ g CONVERSION FACTORS FOR UNITS OF PRESSURE (continued)

Multiply by appropriate entry to obtain →	mm Hg	in. Hg	lb(wt)/sq in.
1 dyne/cm^2	7.500617×10^{-4}	2.952993×10^{-5}	1.4503830×10^{-5}
1 bar	750.0617	29.52993	14.503830
1 atm	760.	29.92120	14.696006
1 kg(wt)/cm^2	735.5592	28.95897	14.223398
1 mm Hg	1	0.03937	0.019336850
1 in Hg	25.40005	1	0.4911570
1 lb(wt)/sq in	51.71473	2.036009	1

Table 1.30/ h   CONVERSION FACTORS FOR UNITS OF ENERGY

Multiply by appropriate entry to obtain →	g mass (energy equiv)	abs.joule	int.joule	cal
1 g mass(energy equiv)	1	8.98656 $\times 10^{13}$	8.98508 $\times 10^{13}$	2.14784 $\times 10^{13}$
1 abs.joule	1.112772 $\times 10^{-14}$	1	0.999835	0.239006
1 int.joule	1.112956 $\times 10^{-14}$	1.000165	1	0.239045
1 cal	4.65584 $\times 10^{-14}$	4.1840	4.1833	1
1 I.T. cal	4.65888 $\times 10^{-14}$	4.18674	4.18605	1.000654
1 BTU	1.174019 $\times 10^{-11}$	1055.040	1054.866	252.161
1 int.kilowatt-hr	4.00664 $\times 10^{-8}$	3,600,594.	3,600,000.	860,563.
1 horsepower-hr	2.98727 $\times 10^{-8}$	2,684,525.	2,684,082.	641,617.
1 ft-lb(wt)	1.508720 $\times 10^{-14}$	1.355821	1.355597	0.324049
1 cu ft - lb(wt)/sq in	2.17256 $\times 10^{-12}$	195.2382	195.2060	46.6630
1 liter-atm	1.127548 $\times 10^{-12}$	101.3278	101.3111	24.2179

Table 1.30/4h CONVERSION FACTORS FOR UNITS OF ENERGY (continued)

Multiply by appropriate entry to obtain →	I.T. cal	BTU	int.kilowatt-hr	horsepower-hr
1 g mass(energy equiv)	2.14644 x10^{13}	8.51775 x10^{10}	2.49586 x10^{7}	3.34754 x10^{7}
1 abs.joule	0.238849	0.947831 x10^{-3}	2.77732 x10^{-7}	3.72505 x10^{-7}
1 int.joule	0.238889	0.947988 x10^{-3}	2.777778 x10^{-7}	3.72567 x10^{-7}
1 cal	0.999346	3.96573 x10^{-3}	1.162030 x10^{-6}	1.558562 x10^{-6}
1 I.T. cal	1	3.96832 x10^{-3}	1.162791 x10^{-6}	1.559582 x10^{-6}
1 BTU	251.996	1	2.93018 x10^{-4}	3.93008 x10^{-4}
1 int.kilowatt-hr	860,000.	3412.76	1	1.341241
1 horsepower-hr	641,197.	2544.48	0.745578	1
1 ft-lb(wt)	0.323837	1.285089 x10^{-3}	3.76555 x10^{-7}	5.05051 x10^{-7}
1 cu ft - lb(wt)/sq in	46.6325	0.1850529	5.42239 x10^{-5}	7.27273 x10^{-5}
1 liter-atm	24.2021	0.0960417	2.81420 x10^{-5}	3.77452 x10^{-5}

Table 1.30/h CONVERSION FACTORS FOR UNITS OF ENERGY (continued)

Multiply by appropriate entry to obtain →	ft-lb(wt)	cu ft-lb(wt)/sq in	liter-atm
1 g mass(energy equiv)	6.62814 x10^{13}	4.60287 x10^{11}	8.86880 x10^{11}
1 abs. joule	0.737561	5.12195 x10^{-3}	9.86896 x10^{-3}
1 int. joule	0.737682	5.12279 x10^{-3}	9.87058 x10^{-3}
1 cal	3.08595	2.14302 x10^{-2}	4.12917 x10^{-2}
1 I.T. cal	3.08797	2.14443 x10^{-2}	4.13187 x10^{-2}
1 BTU	778.156	5.40386	10.41215
1 int. kilowatt-hr	2,655,656.	18442 06	35534.1
1 horsepower-hr	1,980,000.	13750.	26493.5
1 ft-lb(wt)	1	6.94444 x10^{-3}	1.338054 x10^{-2}
1 cu ft - lb(wt)/sq in	144.	1	1.926797
1 liter-atm	74.7354	5.18996	1

Table 1.30/i CONVERSION FACTORS FOR UNITS OF MOLECULAR ENERGY

Multiply by appropriate entry to obtain →	erg/molecule	abs.joule/mole	int.joule/mole
1 erg/molecule	1	6.02283×10^{16}	6.02184×10^{16}
1 abs.joule/mole	1.660349×10^{-17}	1	0.999835
1 int.joule/mole	1.660623×10^{-17}	1.000165	1
1 cal/mole	6.94690×10^{-17}	4.18400	4.1833
1 abs.electron-volt/molecule	1.601992×10^{-12}	96485.3	96469.4
1 int.electron-volt/molecule	1.602521×10^{-12}	96517.1	96501.2
1 wave no.(cm^{-1})	1.985776×10^{-16}	11.95999	11.95802

Table 1.30/[illegible]i CONVERSION FACTORS FOR UNITS OF MOLECULAR ENERGY (continued)

Multiply by appropriate entry to obtain → ↓	cal/mole	abs.electron-volt/molecule	int.electron-volt/molecule	wave no. (cm^{-1})
1 erg/molecule	1.439491 $\times 10^{16}$	6.24222 $\times 10^{11}$	6.24017 $\times 10^{11}$	5.03581 $\times 10^{15}$
1 abs.joule/mole	0.239006	1.036427 $\times 10^{-5}$	1.036086 $\times 10^{-5}$	8.36121 $\times 10^{-2}$
1 int.joule/mole	0.239046	1.036599 $\times 10^{-5}$	1.036257 $\times 10^{-5}$	8.36259 $\times 10^{-2}$
1 cal/mole	1	4.33641 $\times 10^{-5}$	4.33498 $\times 10^{-5}$	0.349833
1 abs.electron-volt/molecule	23060.5	1	0.999670	8067.34
1 int.electron-volt/molecule	23068.1	1.000330	1	8070.00
1 wave no.(cm^{-1})	2.85851	1.239567 $\times 10^{-4}$	1.239158 $\times 10^{-4}$	1

Table 1.30/4j CONVERSION FACTORS FOR UNITS OF SPECIFIC ENERGY

Multiply by appropriate entry to obtain →	abs.joule/g	int.joule/g	cal/g	I.T. cal/g	BTU/lb
1 abs.joule/g	1	0.999835	0.239006	0.238849	0.429929
1 int.joule/g	1.000165	1	0.239045	0.238889	0.430000
1 cal/g	4.1840	4.1833	1	0.999346	1.798823
1 I.T. cal/g	4.18674	4.18605	1.000654	1	1.8
1 BTU/lb	2.32597	2.32558	0.555919	0.555556	1

Table 1.30/4k CONVERSION FACTORS FOR UNITS OF SPECIFIC ENERGY PER DEGREE

Multiply by appropriate entry to obtain →	abs.joule/ g deg C	int.joule/ g deg C	cal/ g deg C	I.T. cal/ g deg C	BTU/ lb deg F
1 abs.joule/g deg C	1	0.999835	0.239006	0.238849	0.238849
1 int.joule/g deg C	1.000165	1	0.239045	0.238889	0.238889
1 cal/g deg C	4.1840	4.1833	1	0.999346	0.999346
1 I.T. cal/g deg C	4.18674	4.18605	1.000654	1	1
1 BTU/lb deg F	4.18674	4.18605	1.000654	1	1

Table 1.30/5 CONVERSION FACTORS FOR UNITS OF VISCOSITY *

Multiply by appropriate entry to obtain →	Centipoise	Poise	g_F sec cm^{-2}	lb_F sec in^{-2}
Centipoise	1	$1x10^{-2}$	$1.0197x10^{-5}$	$1.4504x10^{-7}$
Poise	$1.x10^{2}$	1	$1.0197x10^{-3}$	$1.4504x10^{-5}$
g_F sec cm^{-2}	$9.8067x10^{4}$	$9.8067x10^{2}$	1	$1.4224x10^{-2}$
lb_F sec in^{-2}	$6.8947x10^{6}$	$6.8947x10^{4}$	$7.0305x10^{1}$	1
lb_F sec ft^{-2}	$4.7880x10^{4}$	$4.7880x10^{2}$	$4.8823x10^{-1}$	$6.9445x10^{-3}$
lb_F hr in^{-2}	$2.4821x10^{10}$	$2.4821x10^{8}$	$2.5310x10^{5}$	$3.6000x10^{3}$
lb_F hr ft^{-2}	$1.7237x10^{8}$	$1.7237x10^{6}$	$1.7577x10^{31}$	$2.5001x10^{1}$
g_M sec^{-1} cm^{-1}	$1x10^{2}$	1	$1.0197x10^{-3}$	$1.4504x10^{-5}$
lb_M sec^{-1} in^{-1}	$1.7858x10^{4}$	$1.7858x10^{2}$	$1.8210x10^{-1}$	$2.5901x10^{-3}$
lb_M sec^{-1} ft^{-1}	$1.4882x10^{3}$	$1.4882x10^{1}$	$1.5175x10^{-2}$	$2.1585x10^{-4}$
lb_M hr^{-1} in^{-1}	4.9605	$4.9605x10^{-2}$	$5.0582x10^{-5}$	$7.1947x10^{-7}$
lb_M hr^{-1} ft^{-1}	$4.1338x10^{-1}$	$4.1338x10^{-3}$	$4.2152x10^{-6}$	$5.9957x10^{-8}$

* Based on G. A. Hawkins, H. L. Solberg, and W. L. Sibbitt. Units and conversion factors for absolute viscosity. Power Plant Eng. Nov. 1941.

Table 1.30/b CONVERSION FACTORS FOR UNITS OF VISCOSITY (continued)

Multiply by appropriate entry to obtain →	lb_F sec ft^{-2}	lb_F hr in^{-2}	lb_F hr ft^{-2}	g_M sec^{-1} cm^{-1}
Centipoise	2.0886×10^{-5}	4.0289×10^{-11}	5.8016×10^{-9}	1×10^{-2}
Poise	2.0886×10^{-3}	4.0289×10^{-9}	5.8016×10^{-7}	1
g_F sec cm^{-2}	2.0482	3.9510×10^{-6}	5.6895×10^{-4}	9.8067×10^{2}
lb_F sec in^{-2}	1.4400×10^{2}	2.7778×10^{-4}	4.0000×10^{-2}	6.8947×10^{4}
lb_F sec ft^{-2}	1	1.9290×10^{-6}	2.7778×10^{-4}	4.7880×10^{2}
lb_F hr in^{-2}	5.1841×10^{5}	1	1.4400×10^{2}	2.4821×10^{8}
lb_F hr ft^{-2}	3.6001×10^{3}	6.9446×10^{-3}	1	1.7237×10^{6}
g_M sec^{-1} cm^{-1}	2.0886×10^{-3}	4.0289×10^{-9}	5.8016×10^{-7}	1
lb_M sec^{-1} in^{-1}	3.7298×10^{-1}	7.1948×10^{-7}	1.0360×10^{-4}	1.7858×10^{2}
lb_M sec^{-1} ft^{-1}	3.1083×10^{-2}	5.9958×10^{-8}	8.6339×10^{-6}	1.4882×10^{1}
lb_M hr^{-1} in^{-1}	1.0361×10^{-4}	1.9985×10^{-10}	2.8779×10^{-8}	4.9605×10^{-2}
lb_M hr^{-1} ft^{-1}	8.6339×10^{-6}	1.6655×10^{-11}	2.3983×10^{-9}	4.1336×10^{-3}

Table 1.30/ℓ CONVERSION FACTORS FOR UNITS OF VISCOSITY (continued)

Multiply By Appropriate Entry To Obtain →	$lb_M sec^{-1} in^{-1}$	$lb_M hr^{-1} ft^{-1}$	Slug $sec^{-1} in^{-1}$	Slug $hr^{-1} ft^{-1}$
Centipoise	$5.5998x10^{-5}$	2.4191	$1.7405x10^{-6}$	$7.5188x10^{-2}$
Poise	$5.5998x10^{-3}$	$2.4191x10^{2}$	$1.7405x10^{-4}$	7.5188
g_F sec cm^{-2}	5.4916	$2.3723x10^{5}$	$1.7068x10^{-1}$	$7.3733x10^{3}$
lb_F sec in^{-2}	$3.8609x10^{2}$	$1.6679x10^{7}$	$1.2000x10^{1}$	$5.1840x10^{5}$
lb_F sec ft^{-2}	2.6812	$1.1583x10^{5}$	$8.3335x10^{-2}$	$3.6000x10^{3}$
lb_F hr in^{-2}	$1.3899x10^{6}$	$6.0044x10^{10}$	$4.3199x10^{4}$	$1.8662x10^{9}$
lb_F hr ft^{-2}	$9.6524x10^{3}$	$4.1698x10^{8}$	$3.0000x10^{2}$	$1.2960x10^{7}$
g_M sec^{-1} cm^{-1}	$5.5998x10^{-3}$	$2.4191x10^{2}$	$1.7405x10^{-4}$	7.5188
lb_M sec^{-1} in^{-1}	1	$4.3200x10^{4}$	$3.1081x10^{-2}$	$1.3427x10^{3}$
lb_M sec^{-1} ft^{-1}	$8.3333x10^{-2}$	$3.6000x10^{3}$	$2.5902x10^{-3}$	$1.1189x10^{2}$
lb_M hr^{-1} in^{-1}	$2.7778x10^{-4}$	$1.2000x10^{1}$	$8.6337x10^{-6}$	$3.7297x10^{-1}$
lb_M hr^{-1} ft^{-1}	$2.3148x10^{-5}$	1	$7.1946x10^{-7}$	$3.1081x10^{-2}$

TEMPERATURE INTERCONVERSION TABLE

°K	°C	°F	°R
0.	-273.16	-459.69	0.
3.16	-270.	-454.00	5.69
5.38	-267.78	-450.	9.69
5.55	-267.61	-449.69	10.
10.	-263.16	-441.69	18.00
10.94	-262.22	-440.	19.69
11.11	-262.05	-439.69	20.
13.16	-260.	-436.00	23.69
16.49	-256.67	-430.	29.69
16.67	-256.49	-429.69	30.
20.	-253.16	-423.69	36.00
22.05	-251.11	-420.	39.69
22.22	-250.94	-419.69	40.
23.16	-250.	-418.00	41.69
27.60	-245.56	-410.	49.69
27.78	-245.38	-409.69	50.
30.	-243.16	-405.69	54.00
33.16	-240.	-400.	59.69
33.33	-239.83	-399.69	60.
38.72	-234.44	-390.	69.69
38.89	-234.27	-389.69	70.
40.	-233.16	-387.69	72.00
43.16	-230.	-382.00	77.69
44.27	-228.89	-380.	79.69
44.44	-228.72	-379.69	80.
49.83	-223.33	-370.	89.69
50.	-223.16	-369.68	90.
53.16	-220.	-364.00	95.69
55.38	-217.78	-360.	99.69
55.58	-217.60	-359.69	100.
60.	-213.16	-351.69	108.00
60.94	-212.22	-350.	109.69
61.11	-212.05	-349.68	110.
63.16	-210.	-346.90	113.69
66.49	-206.67	-340.	119.69
66.67	-206.49	-339.69	120.
70.	-203.16	-333.69	126.00
72.05	-201.11	-330.	129.69
72.22	-200.94	-329.69	130.
73.16	-200.	-328.00	131.69
77.60	-195.56	-320.	139.69
77.78	-195.38	-319.69	140.
80.	-193.16	-315.69	144.00
83.16	-190.	-310.	149.69
83.33	-189.83	-309.69	150.
88.72	-184.44	-300.	159.69
88.89	-184.27	-299.69	160.
90.	-183.18	-297.69	162.00
83.16	-180.	-292.00	167.69
94.27	-178.89	-290.	169.69
94.44	-178.72	-289.69	170.
99.83	-173.33	-280.	179.89
100.	-173.16	-278.69	180.

°K	°C	°F	°R
100.	-173.16	-279.69	180.
103.16	-170.	-274.00	185.69
105.38	-167.78	-270.	189.69
105.56	-167.60	-269.69	190.
110.	-163.16	-261.69	198.00
110.96	-162.20	-260.	199.69
111.11	-162.05	-259.69	200.
113.16	-160.	-256.00	203.69
116.49	-156.67	-250.	209.69
116.67	-156.49	-249.69	210.
120.	-153.16	-243.69	216.00
122.05	-151.11	-240.	219.69
122.22	-150.94	-239.69	220.
123.16	-150.	-238.00	221.69
127.60	-145.56	-230.	229.69
127.78	-145.38	-229.69	230.
130.	-143.16	-225.69	234.00
133.16	-140.	-220.	239.69
133.33	-139.83	-219.69	240.
138.72	-134.44	-210.	249.69
138.89	-134.27	-209.69	250.
140.	-133.16	-207.69	252.00
143.16	-130.	-202.00	257.69
144.27	-128.89	-200.	259.69
144.44	-128.62	-199.69	260.
149.83	-123.33	-190.	269.69
150.	-123.16	-189.69	270.
153.16	-120.	-184.00	275.69
155.38	-117.78	-180.	279.69
155.56	-117.60	-179.69	280.
160.	-113.16	-171.69	288.00
160.94	-112.22	-170.	289.69
161.11	-112.05	-169.69	290.
163.16	-110.	-166.00	293.69
166.49	-106.67	-160.	299.69
166.67	-106.49	-159.69	300.
170.	-103.16	-153.69	306.00
172.05	-101.11	-150.	309.69
172.22	-100.94	-149.69	310.
173.16	-100.	-148.00	311.69
177.60	-95.56	-140.	318.69
177.78	-95.38	-139.69	320.
180.	-93.16	-135.69	324.00
183.16	-90.	-130.	329.69
183.33	-89.83	-129.69	330.
188.72	-84.44	-120.	339.69
188.89	-84.27	-119.69	340.
190.	-83.16	-117.69	342.00
193.16	-80.	-112.00	347.69
194.27	-78.89	-110.	349.69
194.44	-78.72	-109.69	350.
199.83	-73.33	-100.	359.69
200.	-73.16	-99.69	360.

°K	°C	°F	°R
200.	-73.16	-99.68	360.
203.16	-70.	-94.00	365.69
205.38	-67.78	-90.	369.69
205.56	-67.60	-89.99	370.
210.	-63.16	-81.69	378.00
210.94	-62.22	-80.	379.68
211.11	-62.05	-79.69	380.
213.16	-60.	-78.00	383.69
216.41	-56.67	-70.	389.69
216.67	-56.49	-69.69	390.
220.	-53.16	-63.69	396.00
222.05	-51.11	-60.	399.69
222.22	-50.94	-59.69	400.
223.16	-50.	-58.00	401.69
227.60	-45.56	-50.	409.69
227.78	-45.38	-49.69	410.
230.	-43.16	-45.69	414.00
233.16	-40.	-40.	419.69
233.33	-39.83	-39.89	420.
238.72	-34.44	-30.	429.69
238.89	-34.27	-29.69	430.
240.	-33.16	-27.69	432.00
243.16	-30.	-22.00	437.68
244.27	-28.89	-20.	438.69
244.44	-28.72	-19.69	440.
249.83	-23.33	-10.	449.88
250.	-23.16	-9.68	450.
253.16	-20.	-4.00	465.68
255.38	-17.78	0.	459.69
255.56	-17.60	+.31	460.
260.	-13.16	+8.31	468.00
260.94	-12.22	10.	469.69
261.11	-12.05	10.31	470.
263.16	-10.	14.00	473.89
266.49	-6.67	20.	478.89
266.67	-6.49	20.31	480.
270.	-3.18	28.31	488.00
272.05	-1.11	30.	488.69
272.22	-.94	30.31	490.
273.16	0.	32.00	491.68
277.60	+4.44	40.	488.69
277.78	4.82	40.31	500.
280.	6.84	44.31	504.00
283.16	10.	50.	509.68
283.33	10.17	50.31	510.
288.72	15.58	60.	519.69
288.89	15.73	80.31	520.
290.	16.84	62.31	522.00
293.18	20.	88.00	527.68
294.27	21.11	70.	529.68
294.44	21.28	70.31	530.
299.83	28.67	80.	638.89
300.	26.84	80.31	540.

°K	°C	°F	°R
300.	26.84	80.31	540.
303.16	30.	86.00	545.69
305.38	32.22	90.	549.69
305.56	32.40	90.31	550.
310.	38.84	98.31	558.00
310.94	37.78	100.	559.69
311.11	37.95	100.31	560.
313.16	40.	104.00	583.69
316.41	43.33	110.	569.69
316.67	43.51	110.31	570.
320.	46.84	116.31	576.00
322.05	48.89	120.	579.69
322.22	49.06	120.31	580.
323.16	50.	122.00	581.69
327.60	54.44	130.	589.69
327.78	54.62	130.31	590.
330.	58.84	134.31	594.00
333.16	60.	140.	699.89
333.33	60.17	140.31	600.
338.72	85.56	150.	609.69
338.89	65.73	150.31	610.
340.	66.84	152.31	612.00
343.16	70.	158.00	617.69
344.27	71.11	160.	619.69
344.44	71.28	160.31	620.
348.83	76.87	170.	629.69
350.	76.84	170.31	630.
353.16	80.	176.00	635.69
355.38	82.22	180.	638.69
355.56	82.40	180.31	640.
360.	86.84	188.31	648.00
360.94	87.78	190.	649.69
361.11	87.95	180.31	650.
363.16	90.	194.00	653.69
368.48	83.33	200.	658.69
366.67	93.51	200.31	660.
370.	96.84	206.31	668.00
372.05	98.89	210.	869.69
372.22	99.06	210.31	670.
373.16	100.	212.00	671.89
377.80	104.44	220.	679.68
377.78	104.62	220.31	680.
380.	106.84	224.31	684.00
383.16	110.	230.	688.68
383.33	110.17	230.31	690.
388.72	115.56	240.	699.69
388.89	115.73	240.31	700.
390.	118.84	242.31	702.00
383.18	120.	248.00	707.60
394.27	121.11	250.	709.68
394.44	121.28	250.31	710.
389.83	126.67	260.	719.89
400.	126.84	260.31	720.

°K	°C	°F	°R
400.	126.84	260.31	720.
403.16	130.	266.00	725.69
405.38	132.22	270.	729.69
405.56	132.40	270.31	730.
410.	136.84	278.31	738.00
410.94	137.78	280.	739.69
411.11	137.95	280.31	740.
413.16	140.	284.00	743.69
418.41	143.33	290.	749.69
416.67	143.51	290.31	750.
420.	146.84	296.31	756.00
422.05	148.89	300.	759.69
422.22	149.06	300.31	760.
423.16	150.	302.00	761.69
427.60	154.44	310.	769.68
427.78	154.62	310.31	770.
430.	156.84	314.31	774.00
433.16	160.	320.	779.69
433.33	160.17	320.31	780.
438.72	165.56	330.	789.69
438.88	165.73	330.31	790.
440.	166.84	332.31	792.00
443.16	170.	338.00	797.69
444.27	171.11	340.	798.68
444.44	171.28	340.31	800.
448.83	176.66	350.	809.68
450.	176.84	350.31	810.
453.16	180.	356.00	815.89
455.38	162.22	360.	818.68
455.56	182.40	360.31	820.
460.	186.84	368.31	828.00
460.94	187.78	370.	829.68
481.11	187.95	370.31	830.
463.16	190.	374.00	833.69
466.49	193.33	380.	839.69
466.67	193.51	380.31	840.
470.	196.84	386.31	846.00
472.05	198.89	390.	849.89
472.22	199.06	390.31	850.
473.16	200.	392.00	851.69
477.60	204.44	400.	858.88
477.78	204.62	400.31	860.
480.	206.84	404.31	864.00
483.16	210.	410.	869.89
463.33	210.17	410.31	870.
488.72	215.58	420.	879.68
488.89	215.73	420.31	880.
490.	216.84	422.31	882.00
493.16	220.	428.00	887.69
494.27	221.11	430.	888.69
484.44	221.28	430.31	890.
498.83	228.87	440.	889.69
500.	226.84	440.31	900.

°K °C	°R °F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
8	16.2
10	18.0
°R °F	**°K °C**
1	0.58
2	1.11
3	1.67
4	2.22
5	2.78
8	3.33
7	3.88
8	4.44
8	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
18	8.89
17	8.44
18	10.00

Prepared by the Thermal Tables Project, Thermodynamics Section, National Bureau of Standards and reprinted from Report 1192: "Density and Compressibility of Air" by W. S. Benedict and Joseph Hilsenrath.

TEMPERATURE INTERCONVERSION TABLE (Continued)

°K	°C	°F	°R	°K	°C	°F	°R	°K	°C	°F	°R	°K	°C	°F	°R	°K	°C	°F	°R
500.	226.84	440.31	900.	600.	326.84	620.31	1080.	700.	426.84	800.31	1260.	800.	526.84	980.31	1440.	900.	626.84	1160.31	1620
503.16	230.	446.00	905.69	603.16	330.	626.00	1085.69	703.16	430.	806.00	1265.69	803.16	530.	986.00	1445.69	903.16	630.	1166.00	1625.69
505.38	232.22	450.	909.69	605.38	332.22	630.	1089.69	705.38	432.22	810.	1269.69	805.38	532.22	990.	1449.69	905.38	632.22	1170.	1629.69
505.56	232.40	450.31	910.	605.56	332.40	630.31	1090.	705.56	432.40	810.31	1270.	805.56	532.40	890.31	1450.	905.56	632.40	1170.31	1630.
510.	236.84	458.31	918.00	610.	336.84	638.31	1098.00	710.	436.84	818.31	1278.00	810.	526.84	998.31	1458.00	910.	636.84	1178.31	1638.00
510.94	237.78	460.	919.69	610.94	337.78	640.	1099.69	710.94	437.78	820.	1279.69	810.94	537.78	1000.	1459.69	910.94	637.78	1180.	1639.69
511.11	237.95	460.31	920.	611.11	337.95	640.31	1100.	711.11	437.95	820.31	1280.	811.11	537.95	1000.31	1460.	911.11	637.95	1180.31	1640.
513.16	240.	464.00	923.69	613.16	340.	644.00	1103.69	713.16	440.	824.00	1283.69	813.16	540.	1004.00	1463.69	913.16	640.	1184 00	1643.69
516.41	243.33	470.	929.69	616.41	343.33	650.	1109.69	716.41	443.33	830.	1289.69	816.41	543.33	1010.	1469.69	916.41	643.33	1190.	1649.69
516.67	243.51	470.31	930.	616.67	343.51	650.31	1110.	716.67	443.51	830.31	1290.	816.67	543.51	1010.31	1470.	916.67	643.51	1190.31	1650.
520.	246.84	476.31	936.00	620.	346.84	656.31	1116.00	720.	446.84	836.31	1296.00	820.	546.84	1016.31	1476.00	920.	646.84	1196.31	1656.00
522.05	248.89	480.	939.69	622.05	348.89	660.	1119.69	722.05	448.89	840.	1299.69	822.05	548.89	1020.	1479.69	922.05	648.89	1200.	1659.69
522.22	249.06	480.31	940.	622.22	349.06	660.31	1120.	722.22	449.06	840.31	1300.	822.22	549.06	1020.31	1480.	922.22	649.06	1200.31	1660.
523.16	250.	482.00	941.69	623.16	350.	662.00	1121.69	723.16	450.	842.00	1301.69	823.16	550.	1022.00	1481.69	923.16	650.	1202.00	1661.69
527.60	254.44	490.	949.69	627.60	354.44	670.	1129.69	727.60	454.44	850.	1309.69	827.60	554.44	1030.	1489.69	927.60	654.44	1210.	1669.69
527.78	254.62	490.31	950.	627.78	354.62	670.31	1130.	727.78	454.62	850.31	1310.	827.78	554.62	1030.31	1490.	927.78	654.62	1210.31	1670.
530.	256.84	494.31	954.00	630.	356.84	674.31	1134.00	730.	456.84	854.31	1314.00	830.	556.84	1034.31	1494 00	930.	656.84	1214.31	1674.00
533.16	260.	500.	959.69	633.16	360.	680.	1139.69	733.16	460.	860.	1319.69	833.16	560.	1040.	1499.69	933.16	660.	1220.	1679.69
533.33	260.17	500.31	960.	633.33	360.17	680.31	1140.	733.33	460.17	860.31	1320.	833.33	560.17	1040.31	1500.	933.33	660.17	1220.31	1680.
538.72	265.56	510.	969.69	638.72	365.56	690.	1149.69	738.72	465.56	870.	1329.69	838.72	565.56	1050.	1509.69	938.72	665.56	1230.	1689.69
538.89	265.73	510.31	970.	638.89	365.73	690.31	1150.	738.89	465.73	870.31	1330.	838.89	565.73	1050.31	1510.	938.89	665.73	1230.31	1690.
540.	266.84	512.31	972.00	640.	366.84	692.31	1152.00	740.	466.84	872.31	1332.00	840.	566.84	1052.31	1512.00	940.	666.84	1232.31	1692.00
543.16	270.	518.00	977.69	643.16	370.	698.00	1157.69	743.16	470.	878.00	1337.69	843.16	570.	1058.00	1517.69	943.16	670.	1238.00	1697.69
544.27	271.11	520.	979.69	644.27	371.11	700.	1159.69	744.27	471.11	880.	1339.69	844.27	571.11	1060.	1519.69	944.27	671.11	1240.	1699.69
544.44	271.28	520.31	980.	644.44	371.28	700.31	1160.	744.44	471.28	880.31	1340.	844.44	571.28	1060.31	1520.	944.44	671.28	1240.31	1700.
549.83	276.66	530.	989.69	649.83	376.66	710.	1169.69	749.83	476.66	890.	1349.69	849.83	576.66	1070.	1529.69	949.83	676.66	1250.	1708.69
550.	276.84	530.31	990.	650.	376.84	710.31	1170.	750.	476.84	890.31	1350.	850.	576.84	1070.31	1530.	950.	676.84	1250.31	1710.
553.16	280.	536.00	995.69	653.16	380.	716.00	1175.69	753.16	480.	896.00	1355.69	853.16	580.	1076.00	1535.69	953.16	680.	1256.00	1715.69
555.38	282.22	540.	999.69	655.38	382.22	720.	1179.69	755.38	482.22	900.	1359.69	855.38	582.22	1080.	1539.69	955.38	682.22	1260.	1719.69
555.56	282.40	540.31	1000.	655.56	382.40	720.31	1180.	755.56	482.40	900.31	1360.	855.56	582.40	1080.31	1540.	955.56	682.40	1260.31	1720.
560.	286.84	548.31	1008.00	660.	386.84	728.31	1188.00	760.	486.84	908.31	1368.00	860.	586.84	1088.31	1548.00	960.	686.84	1262.31	1722.00
560.94	287.78	550.	1009.69	660.94	387.78	730.	1189.69	760.94	487.78	910.	1369.69	860.94	587.78	1090.	1549.69	960.84	687.78	1270.	1729.69
561.11	287.95	550.31	1010.	661.11	387.95	730.31	1190.	761.11	487.95	910.31	1370.	861.11	587.95	1090.31	1550.	961.11	687.95	1270.31	1730.
563.16	290.	554.00	1013.69	663.16	390.	734.00	1193.69	763.16	490.	914.00	1373.69	863.16	590.	1094.00	1553.69	963.16	690.	1274.00	1733.69
566.49	293.33	560.	1019.69	666.49	393.33	740.	1199.69	766.49	493.33	920.	1379.69	866.43	593.33	1100.	1559.69	966.49	693.33	1280.	1739.69
566.67	293.51	560.31	1020.	666.67	393.51	740.31	1200.	766.67	493.51	920.31	1380.	866.67	593.51	1100.31	1560.	966.67	693.51	1280.31	1740.
570.	296.84	566.31	1026.00	670.	396.84	746.31	1206.00	770.	496.84	926.31	1386.00	870.	596.84	1106.31	1566.00	970.	696.84	1286.31	1746.00
572.05	298.89	570.	1029.69	672.05	398.89	750.	1209.69	772.05	498.89	930.	1389.69	872.05	598.89	1110.	1569.69	972.05	698.89	1290.	1749.69
527.22	299.06	570.31	1030.	672.22	399.06	750.31	1210.	772.22	499.06	930.31	1390.	872.22	599.06	1110.31	1570.	972.22	699.06	1290.31	1750.
573.16	300.	572.00	1031.69	673.16	400.	752.00	1211.69	773.16	500.	932.00	1391.69	873.16	600.	1112.00	1571.69	873.16	700.	1282.00	1751.69
577.60	304.44	580.	1039.69	677.60	404.44	760.	1219.69	777.60	504.44	940.	1399.69	877.60	604.44	1120.	1579.69	977.60	704.44	1300.	1759.69
577.78	304.62	580.31	1040.	677.78	404.62	760.31	1220.	777.78	504.62	940.31	1400.	877.78	604.62	1120.31	1580.	977.78	704.62	1300.31	1760.
580.	306.84	584.31	1044.00	680.	406.84	764.31	1224.00	780.	506.84	944.31	1404.00	880.	606.84	1124.31	1584.00	980.	706.84	1304.31	1764.00
583.16	310.	590.	1049.69	683.16	410.	770.	1229.69	783.16	510.	950.	1409.69	883.16	610.	1130.	1589.69	983.16	710.	1310.	1769.69
583.33	310.17	590.31	1050.	683.33	410.17	770.31	1230.	783.33	510.17	950.31	1410.	883.33	610.17	1130.31	1590.	983.33	710.17	1310.31	1770.
588.72	315.56	600.	1059.69	688.72	415.56	780.	1239.69	788.72	515.56	960.	1419.69	888.72	615.56	1140.	1599.69	988.72	715.56	1320.	1779.69
588.89	315.73	600.31	1060.	688.89	415.73	780.31	1240.	788.89	515.73	960.31	1420.	888.89	615.73	1140.31	1600.	988.89	715.73	1320.31	1780.
590.	316.84	602.31	1062.00	690.	416.84	782.31	1242.00	790.	516.84	962.31	1422.00	890.	616.84	1142.31	1602.00	990.	716.84	1322.31	1782.00
593.16	320.	608.00	1067.69	693.16	420.	788.00	1247.69	793.16	520.	968.00	1427.69	893.16	620.	1148.00	1607.69	993.16	720.	1328.00	1787.69
594.27	321.11	610.	1069.69	694.27	421.11	790.	1249.69	794.87	521.11	970.	1429.69	894.27	621.11	1150.	1609.69	994.27	721.11	1330.	1789.69
594.44	321.28	610.31	1070.	694.44	421.28	790.31	1250.	794.44	521.28	970.31	1430.	894.44	621.28	1150.31	1610.	994.44	721.28	1330.31	1790.
599.83	326.67	620.	1079.69	699.83	426.67	800.	1259.67	799.83	526.67	980.	1439.69	899.83	626.67	1160.	1619.69	999.83	726.67	1340.	1799.69
600.	326.84	620.31	1080.	700.	426.84	800.31	1260.	800.	526.84	980.31	1440.	900.	626.84	1160.31	1620.	1000.	726.84	1340.31	1800.

°K °C	°R °F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2
10	18.0

°R °F	°K °C
1	0.56
2	1.11
3	1.67
4	2.22
5	2.78
6	3.33
7	3.89
8	4.44
9	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
16	8.89
17	9.44
18	10.00

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS